XIX. *Further experiments upon the colour-relation between certain lepidopterous larvæ, pupæ, cocoons, and imagines and their surroundings.* By Edward B. Poulton, M.A., F.R.S., F.L.S., &c.

[Read October 5th, 1892.]

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A. Introductory.

My attention was first directed to this subject by the writings of Meldola, and especially his editorial notes to Weismann's 'Studies in the Theory of Descent.' His statements recalled my own early experience of the variations in colour of the larvæ of *Smerinthus ocellatus* when found on different food-plants. I therefore determined to experiment upon this species and other *Sphingidæ* which were also known to vary under similar conditions. I first experimented (1884) upon *Smerinthus ocellatus* and *Sphinx ligustri*, and proved that the shade of green can be modified in both these species (Proc. Roy. Soc., No. 237, 1885, p. 269). At the same time I showed that the effect cannot be *phytophagic* in the strict sense of the word, but rather *phytoscopic* (*l. c.*, pp. 306—308), inasmuch as the colour of the surface of the leaf rather than its substance acts as the stimulus. In 1885 these results were extended and confirmed by further experiments on *S. ocellatus* (Proc. Roy. Soc., No. 243, 1886, p. 135). For some years I continued working at this species, and expended a vast amount of unproductive labour upon it. At some future time I hope to extract from the voluminous notes of several years' work a comparatively few details which may be of interest. At that time no one believed that this susceptibility was of common occurrence, and could produce far wider differences in many well-known larvæ, which were therefore more suited for an investigation into the conditions and limits of the change which takes place. A suggestion made by Lord Walsingham first turned my attention from the *Sphingidæ* in the direction of far better material. This suggestion was that the larvæ of *Rumia cratægata*, sometimes green and sometimes brown, might perhaps be found susceptible to these influences. I first experimented upon them in 1886, and in that and the subsequent years investigated many species of *Geometræ* and *Noctuæ*. The general results of this work have been very briefly stated from time to time ('Colours of Animals,' Internat. Sci. Series, London, 1890, pp. 150—153, British Assn., 1887, 1892, Trans. Ent. Soc., Lond., &c.), but the details have never been given. At the same time, the complete establishment of a principle such as this demands the publication of the fullest detail, at any rate as regards many of the species first investigated. When the principle has been proved, the same evidence is not necessary in all cases.

I am now therefore bringing together the results of all my notes of these experiments upon lepidopterous larvæ, omitting those upon the *Sphingidæ*. These details, together with the confirmatory results obtained by Mr. Perkins upon *Boarmia rhomboidaria* (unpublished), and by Miss Gould and Mr. Bateson as published in these Transactions for the present year (pp. 215 and 205), will, I think, leave no room for doubt as to the importance and prevalence of this principle as regards Lepidoptera. It will be interesting in the future to test its applicability to other species, but the greatest interest and importance now attaches to the attempt to acquire further knowledge of the physiology of the process. Certain solid contributions (so far as they go) towards this end will be found in the subsequent experiments, and especially those upon *Amphidasis betularia* in the present year (1892).

As regards the susceptibility of certain exposed pupæ, I began to experiment in 1886 upon *Vanessidæ* and *Pieridæ* (Phil. Trans. Roy. Soc., vol. 178 (1887), B, pp. 311—441). Since then I have again experimented upon the same species, as well as others, but, as in the larvæ, only the most general statement of results has been made ('Colours of Animals,' pp. 110—142). The details now published, together with the confirmatory results obtained by Mr. G. C. Griffiths (Trans. Ent. Soc., 1888, p. 247), Rev. J. W. B. Bell, Mr. Pembery (both in 'Midland Naturalist,' Dec., 1889, pp. 289, 290), Mr. W. H. Jackson (Linn. Soc. Trans., vol. v., 1890, pp. 156, 157), Mr. P. C. Mitchell, quoted by Mr. Jackson (*l. c.*), Mr. Bateson (these Transactions, 1892, p. 205), Mr. Merrifield (Proc. Ent. Soc. Lond., 1892, p. xxx), will leave no doubt about the importance of the principle as regards exposed pupæ of Lepidoptera, and here, too, future work will best be concentrated upon the attempt to make out the physiology of the process. In this case, however, far more has been done, as will be seen by an examination of my previous paper (Trans. Roy. Soc., *l. c.*), and the details of experiments during 1892 upon *Vanessa io* and *V. urticæ* which are to be found in this paper.

My conclusions as regards the modification of colours of cocoons have been shown to be erroneous by Mr. Bateson (Trans. Ent. Soc., 1891 and 1892); although there was no doubt about the colour-change itself. This he has shown, in the cases of *Eriogaster lanestris* and *Saturnia carpini*, to be due to disturbance of the larvæ, and not to surrounding colours. It is probable that this criticism affects the conclusions as regards other species (*Liparis auriflua* and *Rumia cratægata*). It is likely, however, that the principle still holds good in the genus *Halias*, inasmuch as my earlier observations (Proc. Ent. Soc., 1887, pp. l, li) have been confirmed by Mr. Tutt's recent publication ('Journal of Variation'), as well as by a few experiments of my own during 1892, published in this paper. The negative results of certain other experiments upon cocoons are also given.

The details of experiments upon the colours of the imago are also recorded below. The species selected was *Gnophos obscurata*, and the results were completely negative.

In certain cases the investigation of the susceptibility of one stage has given information as to that of other stages. Thus in the case of *Gnophos obscurata*, the colours of the cocoon and of the larva were tested incidentally in testing those of the imago. In such cases the chief object of the research has determined the class into which it has been placed in the arrangement adopted below.

B. Experiments upon Lepidopterous Larvæ, 1886—1892.

In the following arrangement the experiments upon *Noctuæ* will be considered before those on *Geometræ*, and in each of these groups of experiments the order will chiefly follow that of time, and also to some extent the importance or completeness of the results, the earlier and less satisfactory results being considered first.

1. *Experiments in 1886 upon Mamestra brassicæ, Hadena oleracea, and Euplexia lucipara.*—The experiments were conducted upon captured larvæ, and were therefore far less satisfactory than those upon hatched larvæ. The progress of the investigation and its results are most concisely given in a tabular form.

I. Dark Surroundings. Dead leaves, &c., intermixed with food-plant.	II. Green Surroundings. Food-plant alone.	III. Green Surroundings. Food-plant alone.
Aug. 28.—5 green *M. brassicæ* (24·3, 23·75, 22·3, 16·25, & 12·5 mm. long), 4 green *H. oleracea* (19·0, 15·6, 11·3, & 9·7 mm. long), and a small brownish green *M. brassicæ*, all found on marigold, were placed in dark surroundings on the same food-plant. To these were also added 3 green *M. brassicæ* (23·9 mm. when found on Aug. 21, 23·0 and 13·5 mm. when found on Aug. 25), and 1 dark green *Euplexia lucipara* (24·5 mm. when found on Aug. 25), all from marigold, and placed up to this date with the *M. persicariæ* in dark surroundings described on p. 299.	Aug. 28. — 4 green larvæ of *M. brassicæ*, 24·0, 22·0, 20·0, and 16·0 mm. long, found on marigold, together with 4 green larvæ of *H. oleracea*, 14·5, 13·25, 12·0, & 8·75 mm. long, were introduced into green surroundings; also another small greenish *M. brassicæ*.	
Aug. 29.—2 *M. brassicæ* had become dark, 1 large and 1 having just changed skin.		
Aug. 30. — 1 small *oleracea* (17·25 mm.) was becoming darker; 4 *brassicæ* had now changed last skins, and 3 were dark; 1 *oleracea* and 2 *brassicæ* were changing skins, and resting on brown leaves; they were removed for examination: 1 large green *brassicæ* added.	Aug. 30.—2 *M. brassicæ* had changed skins and become dark (removed).	Aug. 30.—The 2 removed from II placed here.
Sept. 1.—The 3 larvæ removed Aug. 30 had changed skins, and were all brown; they were replaced. Of the rest, 4 *brassicæ* were brown (3 very dark); 1 *oleracea* was apparently darkening gradually instead of suddenly after an ecdysis. *E. lucipara* still green. 1 green *brassicæ* changing skin on a brown leaf was removed. The large *brassicæ* added Aug. 30 was still green: it was now pupating and removed.	Sept. 1.—1 *M. brassicæ* had changed last skin and become dark (removed).	Sept. 1. — They were a very greenish brown: the third dark larva from II. added.
Sept. 10. — 2 *oleracea* alive; 1 about mature and brown, 1 changing skin and brownish. 6 *M. brassicæ*, all brown. 3 more green *oleracea* added (about 17·5 mm. long). The green larva changing skin and removed Sept. 1 was now dark; it was replaced.	Sept. 10.—3 *H. oleracea* about mature, 2 green, 1 brown. 2 *M. brassicæ*, 1 nearly mature, 1 small; both green. 1 green *oleracea* added, 20·0 mm. long when extended in walking; it was changing its skin.	Sept. 10.—Only 2 found; 1 darkish brown, 1 lightish brown. The latter died; the former was replaced in II.

<table>
<tr><th>I. Dark Surroundings. Dead leaves, &c., intermixed with food-plant.</th><th>II. Green Surroundings. Food-plant alone.</th><th>III. Green Surroundings. Food-plant alone.</th></tr>
<tr><td>Sept. 19.—1 H. oleracea, dead, was brown; 1 ditto, pupating, was brown; 1 ditto, changing skin, was brown; 2 ditto, feeding, were perhaps darkening. 1 M. brassicæ, dead, was brown; 2 ditto, feeding, were brown. There was also 1 pupa of brassicæ.</td><td colspan="2">Sept. 19.— Only 2 brown larvæ, 1 brassicæ and one oleracea; the others remained green. All were dead except 3, but their colours could be made out.</td></tr>
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The results are not at all satisfactory or convincing, because the large proportion of deaths shows that the larvæ were not kept in a normal and healthy condition, and especially because of Miss Gould's negative results with more successfully conducted experiments upon *Mamestra brassicæ* (Trans. Ent. Soc. Lond., 1892, p. 215). At the same time, I should be glad for further experiments to be made, especially with *H. oleracea* and *E. lucipara*. The investigation is far more difficult with such *Noctuæ* as these than with the genus *Catocala* or with *Geometræ*. The larvæ tend to bury or conceal themselves low down on the plant. The abundant fæces very quickly produce the effect of dark surroundings, and, being moist, promote decay in the food-plant. Hence it is very difficult to keep the conditions uniform, and in addition to this, the larvæ are apt to become stained by the semi-liquid material on the floor of the case. All these difficulties could, of course, be obviated, but this would require much time and constant attention. These experiments were conducted at the same time with many other lines of work, and did not receive sufficient care.

I may, however, claim that the results point to the desirability of further investigation upon these or similar dimorphic species.

2. Experiments in 1886 upon Mamestra persicariæ.

These experiments were also conducted upon captured larvæ, and are open to the same objections as those just described. They are given in a tabular form below :—

I. Dark Surroundings. Dead leaves, &c., mixed with food-plant.	II. Green Surroundings. Food-plant only.
Aug. 21.—A green larva of *M. persicariæ*, 17·5 mm. long, found on marigold, placed same day on same food with brown surroundings, dead leaves, &c.	Aug. 21.—A green larva of *M. persicariæ*, 11·3 mm. long, found Aug. 19 on *Ribes americana*, was fed on marigold in green surroundings at this date.
Aug. 25.—Brown paper floor substituted for earth. Larvæ still green. Added at this date 3 more green larvæ, measuring 44·3 (when much stretched), 24·25, & 15·0 mm., found on marigold, except the largest larva.	Aug. 25.—The larva was changing its skin; also introduced 2 green larvæ (20·0 and 22·0 mm. long), the smaller of which was found on marigold at this date.
Aug. 27.—4 larvæ still green, but the largest seemed darker.	Aug. 27.—Examined; all 3 green.
Aug. 28.—6 more larvæ, found on marigold, added, measuring 21·25, 19·5, 16·75, 14·25, and 2 of them 16·0 mm.	Aug. 28.—9 more green larvæ added (22·0, 20·0, 19·5, 17·3, 17·0, 16·0, 15·3, 14·3, and 14·0 mm. long), found at this date on marigold.
Aug. 30.—1 became brown, having changed the last skin, and 25·0 mm. long. The largest was pupating, remaining green (removed); 2 were changing their skins, and resting upon a brown and green leaf respectively; removed in order to note effect. Another larva, 19·0 mm. long, added.	Aug. 30.—1 larva, 26·3 mm. long, has changed skin and become brown (removed); 11 green.
Sept. 1.—Same as Aug. 30, all green but one; some of the green ones appeared to be darkening; 4 in last stage, 1 of which was eating a small larva of same species, although there was plenty of food; 1 in last stage but one; 3 changing last skin, 1 on green, 1 on brown surface; the other placed on a brown surface, and all 3 removed to note effects.	Sept. 1.—All green; 1 dying and removed; 2 more green larvæ added, 16·75 and 23·5 mm. long, the latter changing last skin. The removed larva was now a very greenish brown.
The 2 removed Aug. 30 had now changed their skins, and were both green: they were now replaced.	
Sept. 10.—8 larvæ advanced in last stage, 1 of which had changed in colour before pupation; 1 was dark brown, 4 greenish brown, and 2 brownish green. The greenest was darker than any among the 9 larvæ in II., except a small one in the latter.	Sept. 9.—9 larvæ alive, all in last stage, 8 green, 1 brownish green (a small larva).
Of the 3 removed Sept. 1, 2 were dark brown and 1 was green; the latter was on a brown surface, and 1 of the former on a green surface. they were now replaced.	
Sept. 19.—4 changed in colour before pupation; 4 brown and 1 green at earlier period of growth.	Sept. 19.—Only 2 still feeding, 2 pupating; the rest dead, but no more became brown.

These results are also unsatisfactory. I cannot point with any confidence to the colours of larvæ which had died in the course of the experiments, for the existence of abnormal conditions is only too evident. It is probable that such conditions are to be found in the numbers of the larvæ in these and the previous experiments. Having regard to the habits of the larvæ, in future work it will be well to place very few in each cylinder or case.

The results, however, clearly call for further work, and seem to hold out some hope of positive results. In one respect, however, negative results of much interest are to be gained from the experiments here recorded. In dimorphic (green and brown) species the change from one colour to another in the lifetime of an individual takes place, at any rate as a rule, rapidly in the transition from one stage to another. The larva changes its skin and assumes the other colour. Now, the analogy of the pupal changes of colour made it worth inquiring whether the larva was susceptible to the colours on which it rested during the period before ecdysis. Certain observations were directed to test this possibility in both these and the former series of experiments. In 1 the results were consistent with the existence of such susceptibility, but the evidence was far from strong, inasmuch as the conditions of the larvæ observed were such as to correspond with the general tendency to become brown in the last stage. In these experiments the results are clearly negative, and seem to prove, so far as this species is concerned, that no susceptibility exists at the time in question. In Experiment I. it is recorded that 2 green larvæ were resting, during the last ecdysis, on green leaves, and 1 became brown; while of 3 green larvæ similarly resting on brown surfaces, 2 became green.

3. Experiments in 1888 upon Catocala sponsa.

This experiment was conducted in the early summer of 1888. The larvæ were reared from eggs obtained by George Tate, of Lyndhurst. The food-plant employed was oak.

Experiment I.: Dark Surroundings.

May 15.—11 larvæ were placed on the food-plant intermixed with dark twigs.

May 16.—2 larvæ were removed and placed in green surroundings.

May 20.—More dark sticks were added.

May 27.—Larvæ placed in a larger cylinder with still more dark twigs: all the 9 were alive and healthy.

June 11.—The first larva spun up.

Experiment II.: Green Surroundings.

May 13.—1 larva hatched.

May 14.—5 larvæ hatched.

May 20.—Placed in green surroundings, *viz.*, only the leaves and green shoots visible.

May 27.—Combined with Experiment III. At this date some of the 6 larvæ were light coloured, while others were as dark as those of Experiment I.

Experiment III.: Green Surroundings.

May 16.—2 larvæ hatched, and 2 were transferred from I.

May 20.—Placed in green surroundings.

May 27.—The larvæ of Experiment II. added to these, making 10 altogether.

June 10.—All larvæ were now nearly mature, and were carefully compared together. There was a decided difference between the shade of larvæ exposed to dark surroundings (I.) and those exposed to green (II. and III.). The difference was not nearly so marked as in many other species, e.g., *Crocallis elinguaria*, but was nevertheless distinct, and in the same direction, dark surroundings producing darker larvæ, green surroundings lighter ones.

June 11.—1 became mature and spun up.

As in so many other cases in which these experiments have been made, the dark larvæ are far more perfectly concealed than the light ones, but the latter are much less conspicuous on the leaves than the dark ones would have been. The very rapid development of these large larvæ is somewhat remarkable.

4. Experiments in 1889 upon Catocala electa.

Eggs of this species were kindly sent me by my friend Mr. William White.

May 28: 2 larvæ, at this date about 21·7 mm. long, hatched May 12 and 13, together with 4 larvæ, about 14·5 mm. long, hatched May 16 (2 on this date), 18, and 20, were divided into two lots as equally as possible as regards size and colour, and were subjected to dark and green surroundings respectively.

Experiment I. Dark surroundings.	Experiment II. Green surroundings.
May 28.—3 of the larvæ mentioned above were introduced, abundant dark twigs being intermixed with the food.	May 28.—3 of the larvæ described above placed among leaves and green shoots only.
June 5. — The larvæ compared with those of II., and they were certainly rather darker than the latter. Another small larva was introduced, hatched May 25 or 26.	June 5. — Another small larva introduced, hatched May 25 or 26.
June 14. — Another comparison was made, these larvæ being distinctly, although not strongly, darker than those of II.	
June 17.—Again compared, with the same results: a very fair comparison could be made between the 3 largest of this and the 2 largest of Experiment II.	June 17.—1 has spun up. The difference between the large larvæ here and those of I. is not great, but it is all in the same direction.
June 25.—2 larvæ spun up. The small larva introduced June 5 is now 25·25 mm. long, and very dark, much darker than that in II.	June 25.—2 larvæ spun up. The small larva is 31·4 mm. long.
July 11.—The large larva pupated much earlier. The small one is now mature. The difference is very distinct, but not to be compared with that of *C. elocata*, in which the dark larva is far darker, and the light larva far lighter, showing greater susceptibility in both directions.	July 11. — The remaining larva spun up at this date.

The development of the larvæ is not remarkably rapid, like that of *C. sponsa*. The degree of susceptibility appears to be about the same as in this latter species.

5. Experiments in 1889 upon Catocala elocata.

Eggs were kindly supplied by Mr. William White. The very few larvæ which hatched were arranged in two lots, as in the case of *C. electa*. The food-plant employed was poplar (*Populus nigra*).

Experiment I. Dark surroundings.	Experiment II. Green surroundings.
June 14. — 1 larva introduced; hatched May 27, and 23·0 mm. long	June 14. — 1 larva introduced; hatched May 31, and 21·0 mm. long.
June 25. — The larva was *much* darker than that of II., its length being 32·5 mm. Another larva introduced; hatched June 5, and 22·25 mm. long. It was very light in colour, as up to this date it had been surrounded by leaves alone, *viz.*, under the conditions of II.	June 25. — The larva was 29·0 mm. long. The strong difference between this and that of I. was thus produced in 11 days. Another larva introduced; hatched June 8, and 13·0 mm. long. It was much darker than that introduced into I., but this was partly due to its youth.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings,
June 30.—The difference between the large larvæ of I. & II. continued to be very marked. The small larva was not seen, and was apparently lost.	
July 11. — Between this and the last comparison the difference between the 2 large larvæ had greatly increased, the dark one being almost black. The latter was apparently mature, being larger than that in II. They were therefore painted (July 11), and afterwards preserved (July 13). A few days earlier they were photographed.	July 11. — The large larva had been very light brown for some weeks. The small larva was equally light. Between this date and June 30 the two large larvæ were seen by many physiologists and others (Dr. Burdon Sanderson, Sir William Turner, Prof. C. Stewart, Prof. Gotch, Dr. Page, and Dr. Bradford). Everyone was much impressed with the extraordinary difference between them.

The difference between these larvæ is indicated in an uncoloured illustration to 'Colours of Animals' (p. 151). The larvæ were photographed for me by my friends Mr. F. J. Smith and Mr. G. J. Burch. In both cases they were induced to rest upon white paper spills, and were arranged so that the light fell on the same part of both from the same direction. The photographs did not show nearly so marked a difference as was seen in the larvæ themselves. A collotype reproduction from one of Mr. Burch's negatives is shown on Plate XV., figs. 1 (the dark) and 2 (the light larva). Apart from the colour difference the representation of the larvæ is extremely good.

The number of individuals experimented upon in the case of the *Catocalidæ*, and especially in *C. elocata*, would have been utterly inadequate for the purpose of proving the existence of colour susceptibility. But this principle having been firmly based on the results of experiments with other genera in which very large numbers of individuals have been employed, the evidence now obtained is sufficient to show that the principle applies to the *Catocalidæ*. The mere extension of a principle to fresh cases of the same class does not of course require anything like the same amount of evidence as that which was necessary in the first place to establish the principle itself.

6. Experiments in 1890 upon Catocala fraxini.

Similar experiments were conducted on this species, but I cannot now lay my hands on the notes. However, I remember clearly that the results were similar to those obtained by Miss Gould in the same year, except that my light larvæ did not exhibit a tendency to become greenish, but were very light brown. My results were, in fact, similar to those obtained in the case of *C. elocata*, and both these species may be regarded as extremely sensitive to the colours of their surroundings; while the other *Catocalidæ* investigated, including *C. nupta*, tested by Miss Gould, are far less susceptible. It is very remarkable that closely allied larvæ, belonging to the same genus, should differ so widely in the degree to which they are susceptible. It is possible, however, although not probable, that experiments upon larger numbers may modify these conclusions as regards *Catocala*. It is, however, known that the same difference obtains in the pupæ of certain species of the genus *Papilio* (Phil. Trans. Roy. Soc., 1887, B, p. 408).

We now pass to more numerous and satisfactory experiments upon the larvæ of *Geometræ*.

7. Experiments in 1886 upon the larvæ and pupæ of Ennomos angularia.

The ova were obtained from a captured female, and I believe that all the larvæ hatched from one lot of eggs. The food-plant employed in all cases was elm. The experiments were arranged May 8 and 9.

I. *Dark surroundings.* — The twigs of elm were introduced with the leaves. The larvæ were compared June 12, when there were 23 alive, and all decidedly darker than than those of II. By June 15 they were spinning up rapidly. I am not sure whether there were more twigs added in addition to those bearing the leaves, but probably not, considering the relative darkness of III.

II. *Green surroundings.*—The leaves alone of elm were used. 7 larvæ were alive on June 12, and much lighter than in I.

III. *Darkness.*—The same food-plant, twigs as well as leaves, was covered by a cylinder enclosed in two thicknesses of black tissue-paper. On June 19 they were examined, and 19 were found alive, and were distinctly darker than either of the other lots. This result is exceptional, for larvæ brought up in this way are usually lighter than those among an abundance of dark twigs in strong light.

Other experiments were made to test whether the pupa is susceptible to surrounding colours. I have already described and figured the pupa as dimorphic (Trans. Ent. Soc. Lond., 1885, p. 319, Pl. VII., figs. 20 and 21), "one form being light bluish green, covered with white dots, and the other dark brownish green, sprinkled with black dots." The brown larva becomes green in its cocoon before pupating (*l. c.*, p. 319, and fig. 19). Many larvæ in this condition, and in the earlier brown state, were placed in paper cocoons of various shades,—black, green, white,—but no corresponding differences were seen in the pupæ. I should be glad for this experiment to be tried again, employing more natural substances, such as brown leaves and bark, green leaves, &c., and applying these conditions to a somewhat earlier period of larval life.

There is no doubt that the larvæ of this species are highly sensitive to the greens and browns in their immediate surroundings, but there is at present no reason for the belief that the pupa is similarly susceptible.

8. Experiments in 1886 upon Selenia lunaria.

Moths bred from purchased pupæ paired and laid the eggs which provided the material for these experiments. I am not sure whether all were produced from the same parents. The experiments began June 8—11, when the larvæ were arranged as follows:—

I. *Dark surroundings.* — Fed on *Quercus cerris*, the dark twigs being present as well as the leaves. About 30 were introduced June 9, of which only 19 were alive June 26, and the same number July 13, when they were compared. These larvæ were extremely dark as a whole, and very different from those in II., being much darker than the darkest of the latter.

II. *Green surroundings.* —Fed on leaves of *Quercus cerris* without any dark twigs. Introduced June 9, and 18 alive July 13. They were very variable, but none very dark, and *much* lighter than the larvæ of I. It should be remarked that the leaves of this species of oak are very dark green.

III. *Green surroundings.*—Fed on leaves alone of elm, and from July 3 on variegated elm, the leaves of which are of course much lighter. Introduced June 8, and 5 alive July 13. These were much lighter than II., and 3 out of the 5 extremely light. These larvæ were advanced in size.

IV. *Green surroundings.* — Fed on leaves alone of *Quercus cerris*, in a cylinder surrounded by a single thickness of green tissue-paper, and a roof of the same. 20 larvæ were introduced June 10 and 11, but most had died by June 26, and, on July 13, only 3 small darkish larvæ were left. The paper screen had prevented the leaves from being seen, so that they had become brown and withered, accounting for the failure of this experiment.

There is no doubt that these larvæ are highly sensitive.

9. Experiments in 1887 upon the larvæ and pupæ of Ephyra omicronaria.

(*See Table, page* 307.)

In addition to the experiments of which details are given on the opposite page, there were others which are not noted. Dark surroundings were employed chiefly in the form of intermixture with dead brown leaves, principally of ivy and oak. There was also another set of 11 larvæ reared successfully in almost complete darkness (surrounded by one thickness of black tissue-paper). The larvæ in nearly all cases became pupæ, many dozens being produced, and giving rise to imagos; but, as with the above experiments, the results were invariably negative. Every larva and every pupa was green, and this although large numbers of the latter were fixed to brown leaves, on which they were conspicuous, and although most of the former had been surrounded by these dark objects for nearly the whole of their lives; for the leaves on which the stock of larvæ was kept often became brown, and dark twigs of the food-plant were invariably present during the early stages, if not always (as was the case with most larvæ). There is no doubt that *E. omicronaria* is not sensitive to the surrounding colours.

It must, however, be remembered that the species only exhibits a trace of the dimorphism which is so marked in the allied *E. pendularia* and *E. punctaria*. Nevertheless

9. Experiments in 1887 upon the larvæ and pupæ of *Ephyra omicronaria*.

The eggs from which these larvæ were obtained were laid by probably many moths bred from purchased pupæ. The larvæ began to hatch June 12, and continued to appear for several days. They were kept together until June 26, when the following experiments were arranged. The only food-plant employed was maple.

Dates.	I. Dark Surroundings: Black paper floor and roof, pieces of paper mixed with food-plant.	II. Dark Surroundings: Black paper nearly covering cylinder; black paper floor; dead brown leaves intermixed.	III. Darkness: Double black tissue-paper round sides, and forming roof; floor 1 thickness. Food-plant alone.	IV. Green Surroundings: Green paper floor and roof.	V. Green Surroundings: Green paper roof.	VI. Green Surroundings: White muslin roof. In no one of these Experiments was there apparently great care to exclude dark twigs of food-plant.
June 26	3 larvæ about 12·5 mm. long, and 12 from about 6·0 to about 7·0 mm. long were introduced.	22 larvæ introduced; none so large as the largest in I.	16 larvæ introduced.	Two sets of 3 and 12 larvæ of about the same size as I. introduced.	16 larvæ, rather smaller than those of previous experiments, introduced.	
July 7	All becoming mature and all green; 1 had pupated recently.	Only 7 larvæ found, all green; 12 more small ones added from the "stock" which was not exhausted June 26.	All green.	All green; 2 green pupæ recently formed.	11 alive, 1 about to pupate; all green.	21 larvæ, 1 ready for pupation.
July 14	11 pupæ, all green; 3 green larvæ.	16 green larvæ; 1 green pupa.	5 green pupæ; 8 green larvæ.	6 green larvæ; 8 green pupæ.	3 pupæ and all larvæ green.	5 green pupæ; 14 green larvæ.
Aug. 21	13 imagos had emerged.	5 imagos had emerged; 3 living pupæ.	All 13 emerged.	8 imagos had emerged: 4 pupæ had been preserved.	9 imagos had emerged.	6 imagos had emerged.

brown varieties of the larvæ of *E. omicronaria*, producing brown pupæ, are not unknown, for I bred one in 1883 (Trans. Ent. Soc. Lond. 1884, p. 51, and Plate I., fig. 10). It would be desirable to repeat these experiments upon other species of the genus.

10. Experiments in 1887 upon Melanippe montanata.

A female captured at Oxford laid the eggs from which the larvæ of these experiments were hatched.

Experiment I. Dark surroundings: dead leaves and bits of brown stick intermixed with food-plants (primrose and polyanthus).	Experiment II. Green surroundings: green leaves of food-plant alone, but these became brown from time to time towards end of experiment.
June 30.—27 newly hatched larvæ introduced.	June 30. — 23 larvæ from same batch of eggs introduced.
July 17.—27 larvæ; very remarkable difference between these and II., the latter being much lighter.	July 17.—23 larvæ; about 9 mm. long in both I. and II.
July 30. — 27 larvæ; still much darker than II.	July 30. — 20 larvæ; both lots were brown, but these far paler.
Aug. 21.—27 larvæ; the difference was now much less, although these were still probably the darker lot.	Aug. 21. — 19 larvæ; the larvæ had been somewhat neglected, and the leaves had partially become brown, hence the darkening of these larvæ, and smaller difference between the two sets.
Aug. 30. — 27 larvæ; still apparently slightly darker.	Aug. 30.—20 larvæ.

It is quite evident that these larvæ are very sensitive, and can adjust their shade of brown to that of their surroundings, becoming very light in a green environment. Two adjustments took place in the larvæ of Experiment II., for they became at first pale upon the green leaves, and then dark when the leaves were allowed to become brown. The first change is shown to have been complete in a little over a fortnight; it probably occupied a still shorter time.

11. Experiments in 1888 upon Boarmia roboraria.

A few larvæ were obtained from eggs laid by a female moth captured by Mr. Arthur Sidgwick, who kindly allowed me to experiment with them.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.
Aug. 19.—7 larvæ introduced; average length, 11·4 mm. Dark twigs intermixed with food-plant (oak).	Aug. 19.—7 similar larvæ introduced.
Aug. 24.—Older leaves of a darker green were offered at this date. On all other occasions, unless specially noted in this and other experiments, I was careful to use leaves of the same age.	Aug. 24.—Younger leaves of a lighter green were offered at this date.
Sept. 2.—Refed; the average length in both I. and II. was now 16·1 mm.	Sept. 2.—Also refed. The effects of surroundings were already very marked, the experiment having lasted about a fortnight.
Sept. 13.—The average length was now 20·6 mm. The difference in colour was very great. The lightest of these 7 were much darker than the darkest of II. These were rather variable, and marked with various shades of grey and brown. It is true here, as in all experiments with stick-like larvæ, that, except when feeding, they are almost invariably found resting on the twigs.	Sept. 13.—The general effect of the larvæ was greenish; their colour may be described as a light greenish grey; they were very slightly variable in colour and marking.
Sept. 30.—The average length was the same; it is therefore probable that they had ceased feeding for some little time.	Sept. 30.—The difference was as marked as before.
Nov. 12.—The larvæ were carefully compared for the last time: 1 had died. The 6 larvæ were various shades of dark brown, with patches of greenish brown often present, and far darker than those of II.	Nov. 12.—All 7 larvæ were of a light greenish brown. They had now been hybernating, and had not been offered food for a long time.

I had arranged to continue the experiments through the winter, some of the lightest larvæ being exposed to dark surroundings, and *vice versâ*. It would be very interesting to test whether there is any susceptibility at this period when concealment is so especially necessary. It is, however, improbable that any susceptibility exists at this time because of the physiological inactivity of hybernation. It must furthermore almost invariably happen that the larvæ remain resting throughout winter upon surfaces with which they had previously been brought into resemblance. The experiment failed, because only a single larva survived the winter. This individual spun a cocoon May 25th, 1889.

It would also be interesting to continue the experiment beyond hybernation. In the case of *Geometra papilonaria* it has been shown that the larvæ are sensitive to colour influences *before* hybernation but not after, when they become dimorphic. It is improbable that this is the case with *B. roboraria*, in which I anticipate that the susceptibility will be found to continue.

The species is certainly highly susceptible before hybernation.

12. Experiments in 1888 and 1889 upon Geometra papilionaria.

1888.

The experiments in 1888 were conducted upon the larvæ after hybernation, when it is well known to be dimorphic, appearing as green and brown forms.

The hybernated larvæ hatched from one set of eggs were placed in dark and green surroundings early in the spring of 1888, the date being unnoted. They were subsequently compared as follows:—

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.
May 22. — 6 larvæ, much larger than those in II., 3 nearly adult, 2 green and 1 brownish; 3 half-grown, green, with brownish on back.	May 22.—8 larvæ: 1 nearly mature and green; 3 half-grown and green, but more distinctly brownish on back than those in I.; 4 smaller and chiefly brown.
May 27.—1 green one has spun; 1 is brown and the rest green; no further change occurred after this date.	May 27.—4 large and all green, like those in I.; 4 much smaller, 1 brown (very small), 3 brown and green.
June 1.—1 green larva spun.	June 1.—1 green larva spun; 2 of the small ones had become green.
June 7. — The remaining larvæ spun.	June 7.—3 green larvæ spun; 1 small larva remains brown and 3 green.

The results are thus negative. Other experiments I have made, but not recorded, also led to negative results. It is probable that the green or brown form cannot be assumed by any individual as the result of susceptibility to surroundings during the stages which immediately precede that in which they become dimorphic (*viz.*, the last). It is still possible, although unlikely, that some predisposition towards either form may follow from the influence of environment during the earlier stages which are certainly susceptible (as will be shown below). Against such a view must be set the fact that both green and brown forms are found among larvæ which have been kept together in a muslin bag upon the same branch ever since hatching, or at any rate since the first stage. I have observed this several times in different years.

1889.

The experiments in 1889 were conducted upon the larvæ before hybernation. I had already shown that these younger larvæ are certainly susceptible and capable of becoming either light or dark brown, according to the colours of their surroundings (Trans. Ent. Soc. Lond., 1888, p. 593). I was anxious to test this conclusion still further.

On July 3rd about 24 newly-hatched larvæ were placed in a cylinder, and fed upon filbert leaves, surrounded by abundant dark twigs; while an equal number from the same batch of eggs were placed in a similar cylinder, containing the leaves alone. On July 11th the two lots were compared. The larvæ were about 5·25 mm. long, and those in dark surroundings were decidedly, but not strongly, deeper in tint, some effect having thus been produced in about 8 days. Later on in the summer (date unnoted) they were again compared, and the differences were more pronounced. The larvæ did not survive the winter.

It is therefore clear that these young larvæ are distinctly susceptible during the earlier stages, when they are not as yet dimorphic, but only exhibit various shades of brown.

13. Experiments in 1890 upon Phigalia pilosaria.

38 larvæ hatched in a cool cellar a few days before April 26th, when they were first fed (on *Populus nigra* and elm). The experiments did not begin until May 12th, when the larvæ were of an average length of 20 mm. in the curved position of rest. They were then divided among 4 cylinders as follows :—

Dates.	Experiment I. Dark Surroundings (dark twigs).	Experiment II. Dark Surroundings (dark twigs).	Experiment III. Green Surroundings (leaves, &c., alone).	Experiment IV. Green Surroundings (leaves, &c., alone).
May 12	10 introduced.	9 introduced.	10 introduced.	9 introduced.
,, 17	Average length of 31·5 mm. in all experiments. Larvæ on the whole rather darker than those in III. and IV.	As in I.	Distinctly but not greatly lighter when compared as a whole with I. and II. 9 alive.	As in III. 7 alive.
,, 23	All full-fed. As before, slightly darker than III. and IV., but little difference.	Full-fed. As in I.	Full-fed, and most of them seeking pupation.	Full-fed, and 1 seeking pupation.

The fact that there was some noticeable difference probably indicates considerable susceptibility, remembering the late period at which the experiments began, and the rapid growth which at once set in. It is likely that these experiments will prove to be chiefly interesting as showing, with some of those conducted upon *A. betularia* in 1892, the comparatively early stages during which the colours of the mature larvæ are determined in species which possess the power of individual colour-adaptation.

14. Experiments in 1887 and 1888 upon Crocallis elinguaria.

1887.

A batch of eggs of this species, laid by one moth, was sent me, in the autumn of 1886, by Professor Meldola. They hatched in the following spring, and were at first fed in a bottle, being offered privet, hawthorn, and lilac. The latter food-plant was preferred, and, after April 25th, was alone employed. The experiment was begun at this date. The tabular form is unsuited to the notes taken.

April 25.—The largest larvæ were about 15·0 mm. long; 8 were this size or rather smaller, while 4 were much smaller (about 8 mm. long), and 1 intermediate between these two lots. 4 of the larger larvæ and 2 of the smaller were placed in dark surroundings, while the remaining 7 were placed in green surroundings. The two small ones in the latter were subsequently isolated, although the surroundings were still green.

May 23.—5 in green surroundings and 4 in black were now nearly mature, being about 42·0 mm. long. There was a very marked difference between the 2 sets of larvæ, especially on the ventral sides. They were now (8 a.m., May 23) reversed, the 5 being put in dark and the 4 in green surroundings, to test whether rapid changes of colour could occur; 2 in black and the 2 solitary larvæ in green remained small, and were interchanged also.

May 24.—Noon. No change of colour in the interchanged larvæ. All, except 1 large and 2 small dark larvæ and 2 large light ones, were removed for painting.

May 26.—10·30 a.m. The smaller of the 2 dark small larvæ now seemed to have been affected slightly by the green surroundings, for it was somewhat lighter. The others were unchanged, and were now replaced in their original environments. The 2 now replaced in green were about mature, and very light coloured; the other 3, one of which was quite mature, being dark.

The other larvæ were subsequently replaced, and the pupæ of the two lots kept separate. Many eggs were obtained from moths which emerged from the pupæ of dark larvæ, and these formed the material from which the experiments were continued in the following year, as described below.

This experiment showed conclusively that the larvæ are very sensitive to the colour of their immediate environment, and also that the effects are gradual, and cannot be rapidly reversed by changing the surroundings. Greater effects might perhaps have been produced if the 8 larger larvæ had been subjected to experiment at an earlier age.

1888.

These larvæ were obtained from eggs laid by moths developed from the dark larvæ of the previous year. From the arrangement of the eggs it seemed probable that they were the product of a single pair of moths, but it was impossible to feel sure of this. The experiments are shown in tabular form below.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.	Experiment III. Green Surroundings in the dark.
Larvæ hatched and introduced April 27, 29, and May 2. *May* 6.—Dark twigs introduced; 17 larvæ alive. *May* 18.—Larvæ about 19·3 mm. long. A *very* marked difference between these and II.; seems to have appeared suddenly during the last 24 hours. *May* 19.—17 larvæ.	Larvæ hatched April 27, 28, and 29, and introduced same dates. *May* 14.—17 alive; 8 were separated and placed in lots of 3, 3, and 2 in 3 small cylinders, subject to the same conditions; 9 were left in the original cylinder.	Larvæ hatched and introduced April 30 and May 1; 1 added May 4. *May* 14.—15 alive; many had escaped. *May* 22.—14 larvæ.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.	Experiment III. Green Surroundings in the dark.
May 27.—16 larvæ; the least dark twigs were removed and replaced by very black ones. The larvæ were all very dark, 5 being extremely black. They were not quite so large as II.	*May* 27.—*Lot of* 9: Many nearly full-grown; 6 being large and very light, 1 darker. 2 smaller larvæ were much the darkest. A remarkable difference between these 9 and the larvæ of Experiment I. *First lot of* 3 (moderate-sized larvæ when separated May 14).—Larvæ becoming very light, perhaps more so than the lot of 9. *Second lot of* 3 (small larvæ when separated May 14). — Larvæ were still small. *Lot of* 2 (moderate-sized when separated May 14).—Both larvæ becoming *very* light, with a greenish tinge.	*May* 27.—11 larvæ; they were small, darker than II., but *much* lighter than I.
May 30.—9 very dark, although 5 were still blackest. The remaining 7 were removed to another cylinder with similar surroundings; 2 of them were nearly mature and dark, although not so deep a tint as the 9. The 5 smaller larvæ were dark, but varied in depth.	*May* 30.—*Lot of* 9: 7 nearly mature; 6 very light; 1 large one and 2 smaller ones were distinctly darker than the 6, but not like the larvæ of I.	
June 2.—The 5 smaller larvæ were becoming very dark; the 2 large ones had also deepened, but not so much as the others: they were now practically mature. No note as to the 9 dark ones, which were probably unchanged.	*June* 1.—*Lot of* 9: 2 light ones spinning; another matured June 2. *First lot of* 3.—Becoming light; 2 very light, like the lightest of the lot of 9. *Second lot of* 3.—Becoming lighter. *Lot of* 2.—Very light, as light as any in Experiment II.	*June* 1.—The larvæ were now becoming darker rather suddenly; they were considerably smaller than those of I. and II.
June 4.—2 of the darker lot of 9 and 2 of the less dark lot of 7 were preserved. The former were not the blackest individuals.	*June* 4.—*Lot of* 9: 2 light ones spun up, and 1 drowned accidentally; the large darker one preserved: it remained much darker than the others to the end. *First lot of* 3.—1 dead (probably the least light larva); 1 spun and 1 preserved. *Second lot of* 3.—Had become still lighter, especially the 2 larger, which were preserved. No further notes of the remaining larva.	*June* 4.—11 larvæ, a good deal darker than II., but not dark like I., being much nearer to the former; 4 preserved, 1 of which was much lighter than others.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.	Experiment III. Green Surroundings in the dark.
June 6. — *The lot of* 9: 2 had been sent away June 4; the remaining 7 were spinning or just about to spin. They remained extremely dark to the end. *The lot of* 7.—2 had been sent away June 4; 2 were spinning; the remaining 3 were quite dark, like the lot of 9. *June* 10.—Of those left, 1 spun and the remainder were preserved.	*June* 6.—*Lot of* 9: 1 of the darker larvæ spun up; no further notes of the other. They remained comparatively dark to the end, but not like the larvæ of Experiment I. *Lot of* 2. — These very light larvæ were both spinning up.	*June* 8.—2 spun np; now that the larvæ were mature their tint was unchanged. They all remained much darker than II., but far nearer these than the larvæ of I.

These results confirm those of the previous year, and show the great susceptibility of the larvæ. The effects seem to have become prominent somewhat suddenly after about 12 days' exposure to the conditions of experiment.

Experiment III. proved that the larvæ are far more strongly affected by dark surroundings in a strong light than by darkness. This result has been confirmed in other species, and may be considered as established (see especially experiments on *Amphidasis betularia* in 1892).

By far the most important result, however, is found in the fact that the susceptibility to green surroundings was not diminished by the fact that the parent larvæ had been made dark by dark surroundings in the previous year. The comparison between I. and II. leaves no doubt on this point. The rather less complete results in the lot of 9 in II. were probably due to the effect of these large larvæ upon one another. When less crowded the effects were more marked.

There is evidence, then, so far as it can be relied on in one generation, that these marked characters, acquired in a normal manner, and very early in the life of the parents, are not transmitted to their offspring, even in the form of a tendency or bias in one direction rather than another.

15. Experiments in 1889 upon the larvæ and cocoons of Hemerophylla abruptaria.

A captured female laid the eggs from which were obtained the larvæ employed in the following experiments. The great majority of the eggs hatched June 5, a single larva appearing on the 4th. They were fed together until June 17, when the experiment was begun.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.
June 17.—26 larvæ of an average length of 7·4 mm., and most of them 12 days old, were introduced; many very dark twigs (of *Quercus cerris*, &c.) being intermixed with the food-plant.	June 17.—25 similar larvæ surrounded by leaves and green shoots of lilac. Leaves of similar age and from the same plant were supplied to I. Up to this date the 51 larvæ had been fed under the conditions of II., *viz.*, among leaves and shoots, without the intermixture of any dark sticks.
June 30.—Larvæ compared. There was a most remarkable difference between them, these being very dark, almost black. The effect had thus become marked in 13 days or under. The larvæ were of an average length of 15·0 mm.	June 30.—The darkest of these larvæ were probably lighter than the lightest of the others.
July 14.—All the 26 were alive, and very uniformly dark. Their size was about the same as those of Experiment II.	July 14.—The largest larvæ were 31·0 mm. long, and were nearly full-grown. The most usual length was 25·0 mm., some 3 or 4 being much shorter (about 18·0 mm.). All 25 were alive. The colour was extremely uniform, being a pale brown with a greenish tinge in the lightest individuals.
July 25.—2 larvæ had spun up. The 24 remaining larvæ were compared for the last time with those of II. The difference was wonderful, and there was no exception on either side.	July 25.—24 larvæ still feeding, and compared. Both lots were photographed at this date.
July 26.—1 larva had spun up.	July 26.—6 of the largest larvæ were put under the conditions of I., but there was no change.

These larvæ are thus seen to be extremely sensitive.

I was kindly helped by Mr. G. J. Burch in photographing the larvæ. Isochromatic plates were used, and the most favourable results were obtained when the larvæ were exposed for 30 seconds to the light from a small magic lantern (with a paraffin lamp), after passing through a sheet of yellow glass. The larvæ were resting on a piece of black net, and the dark and light varieties were intermixed, so that examples of both were in areas of all degrees of illumination (which differed greatly on the two sides of the net). A collotype of the negative is shown on Plate XV., fig. 3.

The larvæ were painted by Miss Cundell on July 27, and reproductions of the drawings are shown on Plate XIV., figs. 1 and 2. The larvæ are represented of the natural size, and the colour-difference is very well shown, although the attitudes of the resting larvæ are not quite natural. They were probably temporary attitudes assumed after disturbance.

The colours of the cocoons were also tested in these experiments. At first sight the power of adjustment to the surface of attachment seemed to be undoubtedly present, but when I examined the cocoons in 1889, I soon found that the appearance was due to adventitious material being woven into the fabric. The resemblance to surroundings is extremely perfect, and so well packed and so small are the foreign particles that the light brown silk does not in the least interfere with concealment on a dark surface. This is shown in Plate XIV., fig. 2, where a cocoon is represented on the right side of the base of the twig of *Quercus cerris*. When the cocoons were spun on muslin, the larvæ had but little power of gnawing off fragments, and these being few and thinly scattered, the appearance of the cocoon was made up by the light brown silk. Their power of dealing with paper was superior to that of dealing with muslin, but far less than when supplied with bark, which is probably the natural surface on which they spin.

16. Experiments in 1886, 1887, and 1888 upon Rumia cratægata.

1886.

These experiments have a personal interest to me, inasmuch as they first indicated that the power of individual colour-adaptation was widely present among lepidopterous larvæ, and was best studied among the most perfectly concealed forms, rather than among the *Sphingidæ*. I have already said that I owe the suggestion to test this species to Lord Walsingham.

A captured female laid the eggs which furnished the material for this experiment.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.
June 26. — 9 larvæ introduced; dark twigs mixed with the food-plant (hawthorn), black paper floor and roof to cylinder.	June 25.—29 larvæ introduced; leaves only, with green paper floor and roof to cylinder.
June 27.—13 more larvæ added.	
July 14. — Only 4 now alive; small and brown.	July 14.—Only 5 now alive; quite small, and various shades of brown.
July 24.—All but 1 *much* darker than other lot; that 1 about the same as the 3 in the green cylinder.	July 24.—Only three now alive.
Aug. 12.—3 alive; 1 so dark as to be almost black; another larger one was dark brown, mottled with grey; 3rd small and dark brown.	Aug. 12.—Not so large as in I.; the largest was light brown mottled with grey, and with green apparently showing through in many places; the next in size was a little darker brown, with a distinct squarish green patch on each side of the humps on the 3rd abdominal. There was also green in other parts, especially on sides of 6th, 7th and 8th abdominals. The 3rd and smallest was darkish brown.
Aug. 13.—The largest larva was painted (see Plate XIV., fig. 3).	Aug. 13.—A most striking change had taken place in the last 24 hours in the clearing up of the opaque brown pigment, and the consequent appearance of the underlying green. The whole effect was now as much green as brown. This chiefly applied to the 2 larger larvæ; on the 12th they had been brown mottled with green (as the smallest was now); on the 13th they were as much green as brown.
Aug. 28.—The very dark larva continued almost black. There was no trace of green in any of the three.	Aug. 28.—The smaller larva remained the same; the others were not quite so green as on the 13th, but still a distinct greenish brown, a bluish grey "bloom" having appeared on the larger one.
Sept. 5.—The largest had spun up a few days before.	
Sept. 17.—The less dark of the 2 remaining larvæ was painted (see Plate XIV., fig. 4), but both were now very dark, and no trace of green was seen on the darker one, except on using a lens. A little green was present on that which was drawn.	Sept. 17.—The largest, with the "bloom" on it, nearly full-fed, was painted (see Plate XIV., fig. 6); the next in size was much lighter in colour, and a yellowish brown with green appearing through in various parts. The smallest was a dark brownish green, but still much of the latter colour present on it.
Sept. 28.—The 2nd larva painted had spun up.	Sept. 23.—One of the larger ones had spun up a day or two. The lighter large one was painted about this time (see Plate XIV., fig. 7).
Oct. 4.—The darkest larva had just spun up. It had previously been painted (see Plate XIV., fig. 5).	Sept. 26.—The smallest had died; it was lighter than any in I., but not light like the two larger in this experiment.

These results show that the larvæ are very sensitive to the colours of their normal surroundings. This was the first species in which green and brown environments had respectively produced green and brown larvæ. In others the former had merely produced very light brown larvæ, and this is still true of the great majority of species as yet tested. The results determined me to conduct the same experiment more carefully and on a larger scale in the succeeding year.

It is interesting to observe that, although there was so marked a difference between the larvæ in I. and II., considerable individual differences were noticeable in each set. The sets varied in the amount or distribution of darkness and greenness respectively, and in the amount and distribution of "bloom." Although the conditions were the same for each set, the larvæ reacted rather differently, according to their individual predispositions. I find this to be the case in many species, but the results become more and more uniform as the conditions are applied earlier, and as care is taken that they shall be as extreme as possible throughout. But when every precaution is taken, occasional exceptions show that there are sometimes strong individual differences of predisposition. This will appear in some of the experiments on *Amphidasis betularia.*

1887.

(*See Table, pages* 320, 321.)

These larvæ were shown at the British Association at Manchester, and a brief summary of the result is printed in the Report of the Meeting (see Report, 1887, p. 756; also 'Nature,' vol. 36, p. 594). Professor Weismann, who was staying with me before the meeting, compared them carefully; he subsequently alluded to them in his essay, "On the Supposed Botanical Proofs of the Transmission of Acquired Characters" (1888). See Weismann, "On Heredity," Oxford, vol. i., 2nd edition, pp. 406, 407.

One of the chief interests is, however, due to the fact that the moths produced by the larvæ of Experiments II. and III. paired and laid eggs, providing the material for the next year. As the larvæ of II. had been made dark by their surroundings, and the larvæ of III. green, and as the offspring of both were subjected to both these conditions, the test of any hereditary result was unusually complete.

1887.

A captured female *R. cratægata* laid a large number of eggs which afforded the material for the following experiments. The larvæ began to hatch in large numbers on June 24. The experiments began rather over a fortnight later, on July 11, when the larvæ were arranged as follows :—

Dates.	Experiment I. Dark Surroundings: Dark twigs intermixed with food-plant (hawthorn).	Experiment II. Dark Surroundings: As in I., only experiment begun about a fortnight later than in other lots.	Experiment III. Green Surroundings: Leaves and young shoots of hawthorn alone made use of. The leaves became brown on one occasion.	Experiment IV. Green Surroundings: As in III., except that leaves never became brown.	Experiment V. Green Surroundings: As in III., but leaves became brown more than in latter.
July 11 July 26 or 30	About 30 larvæ introduced. July 30.—25 alive.	25 larvæ introduced. July 26.—15 larvæ alive; hardly half-grown; 1 appears to be green, but all others various shades of brown. *Dark sticks added, and experiment begun.*	13 larvæ introduced. July 30. — 9 alive; the leaves had unfortunately become brown. This was not repeated afterwards.	About 20 larvæ introduced. July 30.—Only 7 alive.	17 larvæ introduced. July 26.—12 alive, of various shades of brown. Some leaves had become brown the last few days.
Aug. 8	Refed.	All 15 seem to be getting dark.			12 alive; leaves again allowed to become brown, and remained so a few days.
Aug. 16	3 or 4 advanced in last stage.	1 nearly mature, 1 somewhat smaller, but no others in last stage. Although many were partially green, they are losing it; the older ones especially are brown.	9 alive; mostly in last stage but one, and becoming *very* green in most cases.	7 alive; 2 small in last stage, others smaller still; they were becoming very green indeed; 1 small one was the greenest in any lot.	1 nearly mature and greenish brown; no others in last stage. All but 4 were green rather than brown, although some brown in all. There was a great change towards green since the last examination (Aug. 8). The larvæ were for the most part greener than any obtained in 1886.

Aug. 29 or 30	Aug. 30.—25 alive, very dark.	Aug. 29. — 14 alive; 7 large, all brownish and mostly deep brown, although with a greenish tinge in 2 or 3. A most remarkable difference between these and the larvæ in III., IV. and V. Not quite so dark as I.	Aug. 29. — The 9 larvæ compared with II.; a most striking difference between them. All were green but 1, which was brownish. 4 were large.	Aug. 30. — Greener than V., and about the same as III. 1 larva mature.	Aug. 30.—12 alive; 1 at least pupating. Leaves had again become brown for some little time. These larvæ were not so green as III. or IV.
Sept. 12	24 alive; 2 pupating.	11 feeding, 2 ready for pupation.	1 had spun.	5 feeding, 1 spun up.	1 died; 9 still feeding.
Sept. 15		3 pupating and removed.			
Sept. 22	19 still feeding.	8 larvæ, and 2 spun up.	5 still feeding; all *very* green, except 1, which is darker, but greenish; 2 pupating, 2 pupæ.	5 larvæ, 2 of which are apparently mature. All were distinct green forms, 4 of them being extreme.	9 still feeding. The grey "bloom" was marked in these green ones, and about half had a more or less distinct brownish tinge, especially pronounced in I.
RESULTS.	The darkest larvæ of all these experiments, but not extreme dark varieties like the darkest obtained in 1886. They were nevertheless distinct dark forms, without any but the faintest trace of green. There was, however, a considerable amount of greyish "bloom" on many of them.	The larvæ of II. never became quite so dark as I., the grey being more predominant. They were *very* different from III., IV. and V.	These results were very characteristic of green surroundings, and contrasted most strongly with the effects produced in II., and especially in I.	Results as in III.	These were not nearly such extreme results as those obtained in III. and IV., but they were *far* nearer to the latter than to those of I. and II. The divergence from III. and IV. is easily explained by the longer time during which these larvæ were exposed to brown leaves, and because they were, up to Aug. 30, crowded in a very small cylinder, so that each was much affected by the colour of the others; the larger number of larvæ also contributed to the result.

1888.

The larvæ hatched from eggs laid by moths from Experiment II. (1887) will first be considered. The pupæ of this experiment were kept in one receptacle, and the moths emerged together, so it is impossible to decide upon the number of moths which laid eggs; but the small batch obtained favours the conclusion that only one did so.

The experiments on this lot of larvæ are given below in a tabular form.

Experiment I. Dark Surroundings.	Experiment II. Green Surroundings.
July 1.—12 larvæ introduced, still quite young.	July 1.—12 similar larvæ introduced.
Aug. 5.—10 alive; larvæ were still small and not very dark yet.	Aug. 5.—8 alive; still small. Compared with I., these were decidedly lighter and somewhat greener; they were not as yet very light and green.
Aug. 19.—10 alive; much darker than II., but not so dark as might be expected from the dark surroundings. Most were nearly mature.	Aug. 19. — 8 alive; these were clearly greener and lighter, and good examples of the effect of green surroundings.
Sept. 3.—9 alive; 1 spun. The results were not nearly so marked as in II., but they were much darker than these; 3 of them were grey rather than dark, the remainder being darker, but only one very dark, and this with some green on it.	Sept. 3.—8 alive, 3 having spun up; 2 full-fed and green-grey in colour: the results very characteristic of green surroundings. 3 smaller and not quite so green, but still light varieties.
Sept. 12.—1 more had spun and 7 left.	Sept. 12. — 2 more had spun and 3 left.
Sept. 14. — Still 7 left, and not very dark considering the conditions; 3 were greyish and 1 of the darkest was still greenish. Compared with the larvæ descended from moths of Experiment III., 1887, those in I. (of which only 5 could now be compared safely, because the others had undergone changes preparatory to pupation) were rather darker than these 7, but not much. On the other hand, these 7 were rather darker than the 4 II., and much more so than the 5 IV. There was only 1 III. left for the purposes of comparison, and this seemed to be about the same as these 7.	Sept. 14.—Still 3 left; they were very pale greenish grey, showing distinctly the effects of the experiment, far more than in I. Compared with larvæ from moths of Experiment III., 1887, these 3 were certainly lighter than the 5 IV. now left, much lighter than the 1 III. and 4 II., and far more so than the I.

Conclusions are best deferred until the description of experiments upon moths produced by the larvæ of Experiment III., 1887.

As in the last experiments, it is impossible to decide the number of moths which laid the eggs. The larvæ of these experiments were hatched on June 16th, 1888, and other days not far removed. The young larvæ were kept together until July 3rd, when many were arranged in Experiments I., II., and III. On July 7th a further number were divided between II. and IV.

Dates.	Experiment I. Dark Surroundings (dark twigs).	Experiment II. Dark Surroundings (dark twigs covered with black paper).	Experiment III. Green Surroundings.	Experiment IV. Green Surroundings.
July 3	23 larvæ introduced.	12 larvæ introduced; 8 more added July 7.	36 larvæ introduced.	July 7.—8 larvæ introduced.
July 20	More dark twigs added, although many were present already. Marked effects had been produced.	At this date twigs covered with black paper were substituted for the ordinary dark ones. Their number was gradually increased for about a week.	Examined; much effect was seen to have been produced. 13 larvæ removed from here and introduced into IV.	13 larvæ introduced from III.
Aug. 6	22 larvæ living: compared with others these were considerably darker than any of the others, including II. Only 1 or 2 larvæ were greenish brown, like many of II., and these less distinctly so.	20 larvæ living; many of these larvæ were greenish brown. The slight effect of the black twigs here was one of the most interesting things in this comparison.	21 larvæ living. These larvæ were much greener than I. and II.; only two of them were dark and brownish rather than green, and these not very dark. 1 larva had spun at this date, and 1 previously.	21 larvæ living. These were like III., except that none were very brown. The marked greenness of III. and IV. is remarkable as compared with the less marked darkness of the other 2 lots, even I.
Aug. 19	3 had spun.	3 had spun.	Many had now spun, for the most part a few days previously.	Many had now spun.
Sept. 4	....	Only 8 remained, the rest having spun. The 8 are full-fed and darkish, although by no means extremely dark.	Only 2 remained; both greenish larvæ	
Sept. 14	Only five larvæ could be relied on (the others having spun or changed colour before pupation). They were dark, but not extremely dark forms, but considerably darker than the 7 of Experiment I. descended from moths of II., 1887.	4 larvæ could be relied on. They are of a rather dark greenish brown, certainly darker than IV., but not greatly so.	1 larva only could be compared: it resembled those of II.	5 larvæ could be compared; 4 were of a light greenish brown, and much the lightest coloured larvæ at this date in this set of experiments, 1 resembled II. and III.

Experiment II. is interesting, in showing that black paper-covered sticks are not nearly so effective in producing dark larvæ as dark twigs, although the latter are less black. At the same time it must be remembered that the former tend to become grey from the growth of mould.

The comparison between these and the former larvæ of this year certainly shows that the results produced in the parent larvæ in 1887 were not hereditary. A careful comparison was made on Sept. 14th (see both sets of tables), showing that the larvæ descended from those which had been made green (III. in 1887) were not only darker than those descended from larvæ which had been made dark (II. in 1887), when both were exposed to conditions which tended towards darkness, but the converse was also true, *viz.*, the larvæ of the former set became less green than those of the latter, when both had been subjected to green surroundings. In other words, the tendencies exhibited were rather the reverse of those to be expected by the operation of heredity, and it seems clear that no bias whatever was imparted to the offspring by the conditions to which the parents had been exposed.

In addition to these two sets of experiments, another set was conducted in the same year (1888) upon larvæ hatched from eggs laid by a captured female. These eggs hatched June 18th and 19th. Thus all the larvæ in this set of experiments came from the same parents.

Dates.	Experiment I. Dark Surroundings.	Experiment II. Green Surroundings in dark.	Experiment III. Green Surroundings.
July 1	45 larvæ introduced when quite small.	45 similar larvæ introduced.	45 similar larvæ introduced.
July 21	All had escaped except 3 by gnawing holes in the black tissue-paper roof to cylinder. Black net substituted, and 12 larvæ introduced from II. and III., making 27 here.	34 or 35 larvæ alive. The leaves found to be withered and brown when examined Aug. 19.	39 larvæ alive. Leaves had become very brown. Larvæ had not become green.

<table>
<tr><th>Dates.</th><th>Experiment I.
Dark Surroundings.</th><th>Experiment II.
Green Surroundings in dark.</th><th>Experiment III.
Green Surroundings.</th></tr>
<tr><td>Sept. 4</td><td>12 larvæ alive. They were carefully compared, and no effects were to be seen, all the larvæ of I., II., and III. being darkish. The larvæ in the latter were evidently affected by the frequency with which the leaves had become brown.</td><td>12 larvæ alive; 2 had spun up.</td><td>17 larvæ alive; 1 had spun up.</td></tr>
<tr><td rowspan="2">Sept. 14</td><td rowspan="2">9 alive. Many were now spinning, and the rest nearly mature. This lot is but slightly different from the others, which are practically the same; these are no darker, but exhibit rather less of a greenish tinge than the others.</td><td>10 larvæ alive.</td><td>13 larvæ alive.</td></tr>
<tr><td colspan="2">These larvæ were somewhat greener than in I., but it was a very brownish green; a colour which, however, concealed them very effectually among the greenish brown leaves which surrounded them.</td></tr>
</table>

It is evident that these experiments were treated with some neglect, and the food not changed sufficiently often, so that the leaves became brown, and remained so for some time. The results are, however, interesting, showing that such surroundings produce a powerful influence, no less than those provided by dark twigs; and in the case of Experiment I., it is clear that the effects of the latter were mitigated by those of the former. The results of Experiment II. harmonise with those of other experiments in which darkness produces darkish larvæ intermediate between the effects of dark surroundings and of green surroundings in the light. For this would have been the position of the larvæ in II. had the experiments upon I. and III. been carried out with care.

After the experience I have now had with *Amphidasis betularia*, I should be glad for the experiments on *R. cratægata* to be repeated with the use of other greener food-plants, such as *Populus nigra* (if, indeed, the larvæ would eat this plant). I anticipate that bright green larvæ might be produced in this way without any of the brownish shade or "bloom," either or both of which are usually found when the green surroundings are contributed by hawthorn. It would also be interesting to test the effect of dark lichen-covered twigs on this very sensitive species.

While larva-beating during the past autumn (1892), I have noted the colours of the larvæ of this species beaten from various bushes of hawthorn and blackthorn, and I always found a most marked correspondence between the appearance of the larva and the particular bush on which it had lived. The bushes, even when belonging to the same species, differ greatly in the darkness of their twigs, and the amount of bloom-like superficial colouring. These individual differences were faithfully reproduced, showing the efficiency of the power of colour-relation to surroundings in promoting concealment under normal conditions.

Some of the cocoons produced in these experiments are described in Proc. Ent. Soc. Lond., 1888, p. xxviii, as illustrations of the power of individual colour adaptation, being brown when spun upon green paper and green leaves, but white when spun upon white muslin. I should not now advance these cocoons as examples of the power until after renewed experiments have been made, guarding against the sources of error pointed out by Mr. Bateson.

17. Experiments in 1886, 1889, and 1892 upon Amphidasis betularia.

1886.

A single captured female laid the eggs which produced the larvæ described in the tables below.

When examined and compared Aug. 17th or 18th the sizes of the larvæ were found to vary very greatly, but none had entered the last stage. The following letters were therefore used to express the sizes:—

A.—Changing last skin.
B.—Large in last stage but one; over 30·0 mm. long when extended at rest.
C.—Medium size in last stage but one; over 24·0 mm. long when extended at rest.
D.—Very small in last stage but one, or changing last skin but one.
E.—Earlier stages.

(*See Table, pages* 328, 329.)

In working at experiments such as these, I often note the results in each set of larvæ, without paying attention to the conditions (which are generally indicated by a number or letter). Hence the observations are entirely unbiassed, for I do not know the past history of each set. Subsequently the notes are written out and the conditions described, and then only can the value of the experiment be estimated properly. In the case of the experiments just recorded, this has only just been done, more than six years after the experiments were conducted. Had I written out the results earlier, I should have seen what admirable material was afforded by the larvæ of this species, and should have sought them for more detailed and careful investigation. My general impression at the time the notes were taken was, as is often the case, the reverse of that now gained by a careful study and comparison of the whole course of the experiments. At the time I thought that the larvæ were not susceptible, or but slightly so. I had even less time than usual to do more than take the necessary notes, being exceptionally hurried while this work was progressing.

1889.

The next investigation of this species took place three years later, in 1889, and was the outcome of the accidental capture of a female moth which laid large numbers of eggs. I remembered the tendency of the birch leaves to become brown, and determined chiefly to make use of *Populus nigra*, the large bright green leaves of which will keep fresh for a very long time if the twigs are placed in water.

Most of the experiments were begun July 15, a few days after hatching, when the larvæ were still quite small. The results can be given most concisely in a tabular form.

(*See Table, page* 330.)

I. Ordinary food-plant.	I. A. Dark twigs.	I. B. Blinding Experiment.	II. Green and brown leaves.
Upon birch leaves and twigs (including dark ones) for the whole larval life up to Aug. 18, and retained to the end in many cases.	In I. up to Aug. 18, then dark hawthorn twigs intermixed with food.	In I. up to Aug. 18, then surrounded by green twigs and leaves of birch, 3 out of 5 larvæ being blinded.	Surrounded for about a fortnight with the leaves alone of birch, but these had become old and brown towards end of time.
Aug. 18.—Compared. A. Greyish brown . 1 Greenish brown . 1 Reddish brown . 3 B. Reddish brown 4 Greenish brown . 1 Greyish brown . 2 Greenish . . . 1 C. Light greenish brown . . . 1 Brown . . . . 4 D. Reddish brown 1 Greenish brown . 2 — 21 Many removed for other experiments.	*Aug.* 18.—4 of the B larvæ (2 reddish brown, 1 greenish, and 1 greyish brown, the lighter of the 2), 3 of the C (2 brown and the lighter one), and 1 of the D (the lighter of the 2 greenish brown ones) were introduced from I. at this date.	*Aug.* 18.—The A lot from I. introduced at this date. By Aug. 21 they had changed their last skins, and some were blinded, as follows:— 1 light reddish brown (*blinded*). 1 light reddish brown (*unblinded*). 1 dark reddish brown (*unblinded*). 1 greenish brown (*blinded*). 1 greyish brown (*blinded*).	*Aug.* 18.—Compared. A. . . . . 0 B. Greenish . . 1 Light greenish brown . . . 2 Dark reddish brown 2 C. Reddish brown 3 D. Reddish brown 5 — 13 3 of the B (1 of each colour), 1 of the C, and 2 D (changing last skin but one) removed to dark surroundings (II. A). Fresh green leaves added and brown removed. On Aug. 21 an escaped reddish brown larva (D) was added.
Sept. 3.—All the 8 remaining larvæ in last stage, most being nearly mature, the smallest about half through the stage; 4 green, although not very bright, brown dorsal line present; 1 dull greenish brown; 3 dull reddish brown. The last 4 were not very dark.	*Sept.* 3.—1 a decided green, much brighter than any in I.; 4 very dark smoky brown, much darker than the reddish brown ones in I.; 1 greyish brown, much darker than the greenish brown larva in I. 1 of the dark larvæ pupating.	*Sept.* 3. — The larvæ had a very smoky appearance, especially the blinded ones; the others redder and not so dark as those in I. A.	*Sept.* 15.—1 pupa, 3 nearly mature green larvæ with brown dorsal line.
In feeding the larvæ it is probable that twigs with a great profusion of leaves were employed; hence the absence of very dark forms and the prevalence of green.	The effect of the dark twigs present between Aug. 18 and Sept. 3 is very clear on all the larvæ, except the single bright green one, which seems to have been especially predisposed towards this variety, or more probably may have been older than the others and its colour already determined.	The results are not convincing, because the larvæ were only subjected to these conditions during the last stage; and more careful recent work (1892) shows that they are but little sensitive during this period. Nevertheless, the results are such as to suggest fur ther blinding experiments in the future, and for longer periods of larval life.	The effect of green surroundings predominated in spite of the leaves becoming brown part of the time. This result and that of I. perhaps indicates that the larvæ may have been somewhat predisposed towards the green forms.

II. A. Black paper leaves, &c.	III. Darkness.	IV. Green leaves.	V. Orange paper leaves.
Up to Aug. 18 same surroundings as II.; then brown birch twigs introduced with food, and also pieces of black paper roughly cut into the form of leaves; also black floor and roof.	For about a fortnight, ending Aug. 18, enclosed in a darkened cylinder (covered with one thickness of black tissue paper). Dark twigs of birch not excluded.	Kept for last fortnight on birch leaves and green twigs under a shade of one thickness of faded yellowish green tissue paper.	Kept for about a fortnight on birch leaves and twigs (brown ones included), intermixed with pieces of orange paper cut roughly into the form of leaves.
Aug. 18.—The 6 larvæ which had been removed at this date from II. were now placed in dark surroundings.	*Aug.* 18.—Compared. A. . . . . 0 B. Dark reddish brown . . . 4 C. . . . . 0 D. Reddish brown 2 Light greenish brown . . . 1 — 7 Placed at this date in a larger cylinder covered with 2 thicknesses of black paper and black floor.	*Aug.* 17.—Examined and compared. A. Dark reddish brown . . . 1 B. Dark reddish brown . . . 1 Green . . . . 1 Greenish brown . 3 C. Reddish brown. 3 Light greenish brown . . . 1 D. Reddish brown 3 Light reddish brown . . . 2 — 15 Put in a larger cylinder; tissue paper changed.	*Aug.* 18.—Examined and compared. A. . . . . 0 B. . . . . 0 C. Greenish brown 3 Tending in different degrees towards reddish brown, two being the typical colour 6 D. Reddish brown 1 E. Reddish brown, varying . . . 4 Light greenish brown . . . 1 — 15
Sept. 15.—5 larvæ in last stage, 3 being dark brown and 1 greenish brown; 1 small and reddish brown; 1 pupa.	*Sept.* 15.—Only one larva left; greenish brown.	*Sept.* 15.—1 pupa; 1 nearly mature green larva, with brown along back. Others escaped.	*Sept.* 15.—Only 2 remaining; both distinctly green, with a brown line down back.
The effect of dark surroundings added Aug. 18 is clear when these larvæ are compared with those of II.	Insufficient to draw conclusions, but so far as it goes, the evidence corresponds with later experiments in showing that darkness is not so effective as dark surroundings in a strong light.	Insufficient evidence, but corresponds with II. in showing susceptibility to green surroundings.	Results correspond with those obtained in 1892, showing the power of orange surroundings in producing green larvæ.

A. Dark Surroundings.

I. Cylinder with abundant dark twigs intermixed with food.	II. Same as I.
July 15.—31 young larvæ introduced.	July 15.—30 introduced.
July 24.—Compared on this and following dates. Resting (by day) on the dark twigs were 16 dark, 1 green, and 2 intermediate larvæ. Resting on leaves and green shoots were 3 dark, 3 green, and 6 intermediate larvæ.	July 23.—Compared. Nearly all dark brown; at later dates this tendency became more marked, and finally only 2 exceptions remained, 1 being bright green, and 1 intermediate.
Aug. 5.—3 dark larvæ on leaves; 25 dark larvæ on dark twigs; 1 intermediate larva on dark twigs; 2 brownish intermediate larvæ on dark twigs.	
Aug. 10 and onwards.—The larvæ sought pupation without further change of colour.	Aug. 11.—At this date and onwards the larvæ began to seek pupation.

The extreme susceptibility to dark surroundings is clear from these results. The fact that green surroundings cannot be excluded is no doubt the explanation of the few exceptions. In the converse experiments with green surroundings everything dark can be excluded, and hence exceptions did not occur. The exceptions undoubtedly show individual differences in the degree of susceptibility to green and brown surroundings respectively, although the final result—1 marked exception (the single green larva)—out of 61 individuals shows that such differences are of no great numerical importance in determining the colours of this species. The proportions of light and dark larvæ found July 24, in I., on dark and green surfaces respectively, seem at first sight to suggest the existence of a tendency to seek an environment with the corresponding colour. On Aug. 5, however, nearly all were on the dark twigs; and in 1892 very inappropriate situations were often observed (Experiment XXVI.).

It is also seen that a period of 8 days (July 15 to 23) is sufficient to produce marked effects on the majority of the larvæ.

B. Artificial Dark Surroundings.

A single experiment was made with sticks covered with black tissue paper taking the place of twigs which were naturally dark, like those of I. and II. This and some of the other experiments were begun rather later than those just described; for the whole stock of larvæ was not exhausted on July 15th.

Experiment III.

Black-paper-covered sticks intermixed with food-plant.

July 20	9 larvæ introduced.
Aug. 17	The larvæ were very large. All 9 were very black, at least as dark as those of I. and II.
Aug. 30	4 ceased feeding.
Sept. 4	2 ceased feeding. They remained as dark as ever to the end; 1 was dead by Sept. 5.

This experiment shows that artificial may be as effective as natural surfaces. It is probable that the comparative failure in the case of *R. cratægata* (see p. 324) was due to the growth of mould upon the black paper, making it much lighter in appearance.

C. Very small proportion of dark twigs in surroundings, and comparison experiment with green alone.

Two experiments were then made with the object of testing the susceptibility of the larvæ to a very small proportion of dark material in the environment. Incidentally the effect of green surroundings produced by another food-plant (nut) was also tested, and found to be as effective as that due to *Populus nigra*.

The experiments were arranged as follows:—25 young larvæ were introduced July 20 into a large glass lamp-shade (about 165 mm. high, and the approximate capacity of 1300 cc.). On Aug. 21 they were removed to a larger lamp-shade (204 mm. high, and the approximate capacity of 1900 cc.). These relatively large areas were kept filled with green leaves and shoots of nut, intermixed with which were 5 small dark pieces of dead twig. Three of these were about 40, 65, and 75 mm. long respectively, while 2 of them were about 80 mm. in length; the diameters varied from 3 to 5 mm. They were unbranched, but mostly very rough; 1 was curved, the rest straight. The relation between the sizes of twigs and the smaller glass cylinder first used is shown about ¼ the real size in Plate XV., fig. 4.

In the comparison experiment, 25 larvæ were introduced July 20 into a glass cylinder (about 185 mm. high, 82 mm. internal diameter, and 1000 cc. capacity); and on Aug. 21 they were transferred into two lamp-shades (about 165 mm. high, and the approximate capacity of 1300 cc.). These larvæ were treated exactly as in the former experiment, except that their surroundings were uniformly green, no dark twigs being at any time admitted. The results of the experiments are given below.

Experiment IV. Green Surroundings, with very small proportion of dark material.	Experiment V. Green Surroundings alone.
July 20.—25 larvæ introduced.	July 20.—25 larvæ introduced.
Aug. 12.—8 larvæ were resting on the pieces of dark stick, and 1 was holding a piece by its thoracic legs.	
Aug. 21.—23 larvæ alive; shifted to larger lamp-shade.	Aug. 21.—22 larvæ alive; shifted to two lamp-shades, between which they were equally divided.
Aug. 24.—The larvæ compared (1 unnoted):— *Intermediate* . . 6 *Green* . . . . 4 *Dark* . . . . 12 — 22	
Aug. 26.—1 dark larva dead (about half-grown in last stage).	
Aug. 30.—6 larvæ dead:—4 *dark* (1 large, 3 small in last stage); 2 *green* (small in last stage). The rest carefully compared:— *Green* . . . . 3 *Greenish intermediate* . 2 *Intermediate* . . . . 1 *Brownish intermediate* . 2 *Dark* . . . . 8 — 16	
Sept. 2.—The larvæ were now mostly pupating; 1 had died, and 1 was lost. No further change in the colours.	Sept. 2.—Many were now pupating; all the 22 were alive, and all bright green.

These results are very interesting and remarkable. They show that the susceptibility to dark surroundings is far keener than to green, and this corresponds with the fact that the dark larvæ are much more perfectly concealed than the green. Although the proportion of brown to green in the surroundings may be very small, it is still to the advantage of the average larva of this species to resemble the former, and the average larva does so.

The green larvæ are of a yellower shade than that which appears when they are fed upon *Populus nigra*. This corresponds to the difference between the leaves themselves.

D. Dark Surroundings near the larva, but not actually in contact, and comparison experiment with green alone.

The details of the experiment are described below:—

VI. On green leaves alone, with dark twigs *outside* cylinder.	VII. On green leaves alone, for comparison with VI.
July 23. — 21 larvæ, previously surrounded by green leaves alone, were carefully divided into two lots as much alike as possible; when any difference was unavoidable, the darker larvæ were put in VI., the greener here, in a small cylinder containing green leaves alone, but surrounded by a large cylinder with dark twigs packed between the two.	July 23.—The 21 larvæ divided at this date between VI. and VII. were small and nearly all greenish, except one, which was large and green. The latter was placed here with 10 of the small ones, on the whole *slightly* darker than those in VI.
Aug. 2. — 1 is certainly brown, though not a very dark one; the rest green.	Aug. 2. — All green, or evidently rapidly becoming so.
....	Aug. 4. — 6 are still in last stage but one, 4 in last stage, 1 changing last skin; all bright green, except the smallest, which is changing in that direction.
Aug. 13. — The dark twigs were absent Aug. 6—12. The first became mature. The single larva still remained brown; all others green.	Aug. 13. — The first became mature. From this date onwards the larvæ gradually sought pupation, all being bright green.
Sept. 2. — The dark larva was nearly mature (quite so Sept. 6), and was a brownish intermediate larva. All the others remained bright green, and matured at a rather earlier date.	

Conclusions. — The fact that one larva became brown in VI. is not sufficient evidence that any results were produced, except by the light being somewhat dimmed by the surrounding twigs, and especially by the effects of crowding in a small cylinder. The experiments of 1892 show that both these causes are effective in producing dark larvæ. It is probable that the dark larva is to be accounted for in one of these ways, inasmuch as green surroundings in which such causes did not operate never produced a single dark larva (see below).

E. Green Surroundings.

(*See Table, page* 335.)

The strong susceptibility to green surroundings when nothing brown or dark is present is extremely clear in these results, as well as in the comparison experiments of C and D (V. and VII.). Among the 105 larvæ which matured in these 7 experiments not a single exception occurs.

A very characteristic green larva with a brownish shade along the dorsal area was painted by Miss Cundell, and is represented in Plate XIV., fig. 8. It is shown in a very common attitude, resting on a green twig of *Populus nigra.*

Many of the green and dark larvæ from one of these experiments, and either I. or II., were interchanged for a few days during the last stage. No effects were produced, and it was clear that the larvæ are not susceptible to a short exposure during this period of life.

F. White Surroundings.

Nine larvæ were fed upon *Populus nigra*, the surroundings being green, except for the presence of many white paper spills. The experiment was arranged July 20, and the larvæ were compared with the others Aug. 17. Some of them tended towards green, and some towards light brown, but in both, these colours were, without exception, almost hidden under the predominant whiteness which gave the larvæ a very remarkable appearance, utterly unlike that in any of the other experiments. They were again examined Aug. 24, when the whiteness of the larger larvæ was even more pronounced. They were carefully compared Sept. 2 with 12 of the green larvæ upon nut (Experiment V.); 3 remained small in

E. Green Surroundings.

Leaves and green shoots of the food-plant were alone made use of.

VIII.	IX.	X.	XI.	XII.
July 15.—16 young larvæ introduced. July 23. — 4 largest all bright green, others brownish green. Aug. 5.—15 larvæ found, and all bright green. Aug. 8.—From this date onwards the larvæ matured, remaining bright green to the end.	July 15.—14 introduced. July 24. — All green or greenish. July 28.—All green. Aug. 4.—1 large, 3 moderate-sized, 8 small, 2 changing last skin. Aug. 10.—From this date the larvæ matured, all remaining bright green ; 1 died.	July 15.—15 introduced. July 25. — All green or greenish. .... Aug. 9.—From this date the larvæ matured, and all remained bright green ; 1 died. At this date a chocolate-brown larva found wild upon apple was added to this cylinder to see whether it could change its colour. It was small in the last stage, or at the end of the last but one. It remained dark until mature, when it was eaten by a lizard.	July 15.—16 introduced. July 21. — Mostly about 11·0 mm. long. All greenish, with brown shade on back, and dark beneath. July 28. — All green but one, which is brownish green. The largest is 34·0 mm. long, and bright green. Aug. 4.—10 small in last stage, 1 large, 2 moderate-sized, 3 changing last skin. All now bright green. Aug. 8.—From this date the larvæ matured, remaining bright green.	July 15.—12 introduced. July 23.—All larger ones bright green, and all others changing in that direction. Aug. 4. — 4 small in last stage, 4 large, 2 moderate-sized, 2 changing last skin. All bright green. Aug. 8.—From this date the larvæ matured, remaining bright green.

the last stage, while 6 were nearly full-fed, and these latter were chiefly compared. The white points on the skin appeared to be far more abundant in these 6, and, so far as any green tint appeared, it was of a whitish bluish shade, instead of bright and yellowish, as in all the larvæ upon nut.

The green blood from 2 white and 3 bright green larvæ was then compared, to see whether any difference in the shade of green was due to its colour. There was some individual difference in the tint of the blood, but this was true of both sets of larvæ. It was clear that no explanation was thus to be found, and that the seat of effective colour was in the skin and the structures immediately below it.

The three smaller larvæ were also white; and although 1 tended towards a dark variety, the tendency was obscured by the whiteness.

These results were so remarkable that, although there was no exception, I did not venture to publish them until I had obtained confirmation. This, however, has been forthcoming in the experiments of the past summer (1892), and the results have now been seen by many naturalists.

G. Effect of unsuitable food upon colour-relation.

On July 20, 21 young larvæ were introduced into a cylinder, and supplied with lilac-leaves, dark twigs being abundantly intermixed with the food-plant. The larvæ were observed as follows:—

July 20.—21 young larvæ introduced.

Aug. 9.—11 alive, but small for age.

Sept. 4.—5 alive, but quite small for age; reddish brown in colour.

Sept. 25.—3 still alive, although these subsequently died.

It is therefore probable that the unsuitable food, which prevented the larvæ from attaining maturity, did not interfere with their susceptibility to the colours of the environment. The results observed on Sept. 4 show that all the 5 surviving larvæ harmonized with the dark surroundings. In order to furnish conclusive proof that this result was due to true susceptibility, and not to pathological change, it will be necessary to repeat the experiment, employing green surroundings alone. Such an experiment was attempted as a comparison with the above, but the 21 larvæ had all died by Sept. 4.

The chief results of these experiments, as regards green and dark surroundings, have been briefly mentioned in 'Colours of Animals,' pp. 152, 153, where a dark and light form are represented by uncoloured illustrations.

These experiments at once proved that *A. betularia* was by far the most suitable species for the purposes of this investigation; and I tried to obtain eggs in the succeeding years. In this I was unsuccessful until the present year, in which a much larger series of more careful experiments have been conducted.

The pupæ obtained from these experiments were carefully separated, and the attempt was made to breed from the imagos which emerged. The great majority, however, died in the pupal state, and those which emerged did not pair.

As the moths are well known to vary in darkness, I noted the colours of those few which emerged, but found that there was no relation between the larva and imago in this respect.

1892.

This is by far the most extensive series of experiments upon the modification of the colours of larvæ by the environment that I have ever undertaken. The results obtained in 1889 not only proved that this is the most sensitive larva as yet subjected to experiment, but also that it is most satisfactory to breed, and in every way the most suitable for the purposes of this investigation. I was therefore very anxious to repeat the experiment on a larger scale, and especially to test again the effects of white surroundings, which had produced such remarkable results on the previous occasion; also to make use of other artificial colours, as well as the natural tints of twigs of various kinds and conditions.

A captured female laid a very large number of eggs, of which probably about 200 were sent to Mr. Bateson; these unfortunately hatched during his absence from home, and the larvæ died. The remaining eggs began to hatch in large numbers on June 29th, and all the larvæ appeared in a few days. The majority of these were at once placed in a cylinder, and fed upon the leaves and green shoots of *Populus nigra*, being thus kept in green surroundings, although just before they were re-arranged many of the leaves had become withered and brown. The susceptibility of larvæ during these early stages, if any exists, has been shown not to interfere with such experiments. These larvæ formed the stock from which, when they were rather older, the majority of the experiments were supplied. They will be alluded to below as "the first stock."

As soon as the larvæ began to hatch, a mass of the eggs was separated, and placed (June 29th) in green surroundings in complete darkness until 11 p.m., when it was exposed to the light of a paraffin lamp until 9.10 a.m. the following morning, when it was again placed in darkness. Under these conditions the larvæ hatched, and they constitute "the second stock," from which several experiments were supplied. This alternation of darkness and lamp-light was continued in some of the experiments until the evening of August 2nd. The changes were made every day, and the fixed times were never departed from by so much as an hour.

All the larvæ which hatched from the eggs were made use of in the experiments, except 30, which were sent to Mr. Bateson, and were experimented upon by him with results published in this volume (p. 213), and 80, which were placed on a tree (*Populus nigra*) in muslin bags. These last were intended for experiments, which, however, I was unable to undertake.

The sizes of the glass vessels in which the larvæ were kept are given, because the amount of crowding is shown to exercise a considerable influence on the colour.

When measurements are stated, it must be understood that they were taken when the larvæ were at rest in the rigidly straight position which is characteristic of *Geometræ*.

The experiments are so numerous that it has been necessary to classify them, and treat the various classes separately. The following table indicates the arrangement pursued, and serves as a guide to any particular experiment:—

	Experiments.
A. Dark Surroundings (in addition to the necessary green leaves of the food-plant) :—	1. *Natural* :—I. Black twigs ; II., brown twigs ; III., IV. and V., reddish twigs or stalks, becoming blackish ; VI., brown leaves ; VII., red leaves, becoming blackish.
	2. *Artificial* :— VIII. Black enamelled smooth twigs ; IX., black enamelled rough twigs.
	3. *Dark Surroundings near the larvæ, but not actually in contact* :—X. Dark twigs.
B. Green Surroundings :—	1. *Natural* :—XI., XII. and XIII. Green leaves and shoots of food-plant (*Populus nigra*) ; XIV., leaves and shoots of food-plant, with golden-green twigs intermixed.
	2. *Artificial* :—XV. Green paper spills ; XVI., dark green enamelled rough twigs ; XVII., dark green enamelled smooth twigs ; XVIII., light green enamelled twigs.
C. Similar Surroundings in dim Light :—	XIX. Dark twigs ; XX., red stalks, becoming blackish ; XXI., green leaves and shoots of food-plant ; XXII., dark twigs ; XXIII., green leaves and shoots.
D. Similar Surroundings in Darkness :—	XXIV. Dark twigs ; XXV., green leaves and shoots of food-plant.
E. Transference Experiments :—	XXVI. Transferred from green to dark surroundings ; XXVII., transferred from dark to green surroundings.
F. White Surroundings :—	XXVIII. White paper spills ; XXIX. and XXX., white enamelled twigs.
G. Surroundings of other Colours :—	XXXI. Dark blue paper spills ; XXXII., blue spills ; XXXIII., orange spills and pieces of paper ; XXXIV., orange enamelled twigs.

During the critical period of all these 34 experiments the same food was made use of—the leaves of the black poplar (*Populus nigra*). Great care was taken to ensure that the larvæ were supplied with leaves of the same age, and it may be safely concluded that no effects were produced by the different condition of the food-plant in the various experiments.

The conditions described above were kept up in all cases until August 3rd, when the larvæ were packed for removal to Edinburgh, in order that they might be exhibited at the British Association. After this date they were fed irregularly, and sometimes upon other food-plants, while the conditions of some of the experiments were relaxed ; but only in the case of larvæ which were advanced in the last stage, and long past the period at which change of colour is possible. Whenever there was any possibility of further change, the conditions were carefully adhered to.

The majority of the larvæ were also arranged in cases more suitable for travelling than those in which they had been previously kept. During the susceptible stages clear glass vessels were always employed; some of these were cylindrical, others of the shape shown in Plate XV., fig. 4, bulging in part of the length and contracted at both ends, although often to an unequal extent, while the bulging was nearly always closer to one end than the other. These will be called *lamp-shades* in the description of the experiments, and their heights and approximate capacities will also be given. The former will be called *cylinders*, and their heights, internal diameters, and approximate capacities will also be furnished. Each glass receptacle was placed on a plate perforated by a hole, through which the stalks of the food-plant passed into water below. The food-plant was invariably represented by green leaves and shoots alone, whether other surroundings were made use of or not.

The details of the experiments will now be given in order.

A. Dark Surroundings.

(In addition to the necessary green leaves of the food-plant).

1. *Dark Objects which are natural to the Larvæ.*

(*See Table, pages* 342, 343, *and* 344.)

The results of these experiments are a great advance upon those of 1889. Instead of merely proving that dark larvæ are produced by dark surroundings, we now know that each of certain varied tints which are liable to occur in a dark environment produces its appropriate effect.

Thus black twigs produce black larvæ (I. and fig. 10); brown twigs produce brown larvæ (II. and figs. 11 and 12); light brown mottled leaves produce larvæ which harmonise with them (VI. and fig. 14).

I omit Experiments III., IV., V., and VII., because the results were complicated by the environments altering during the course of the experiment. But the results in reality harmonise with those given above, for the dark larvæ were never like those of I., but tended more in the direction of the mouldy, dark grey, or blackish appearance of the twigs or leaves. Sometimes, however, the larvæ were evidently affected to the end by the earlier appearance of their environment.

Some conclusions as to the period of greatest susceptibility may also be drawn from these results. The facts that the single exception in I. was older than the other larvæ,—that the larvæ transferred from II. to XXVII. for nearly the whole of the two last stages could change so little,—that the larvæ of IV. were considerably darker than III., in which the environment changed more slowly,—and that the earlier colour of the surroundings produced its full effect long after its change, in certain mature larvæ of III., IV., and VII.,—clearly indicate that the time of chief susceptibility has been passed when the last stage but one has been reached. It is equally clear, however, that there is some susceptibility in certain larvæ during the last two stages. On the other hand, the condition of the larvæ during the earliest period of growth does not seem to produce any effect, or at any rate does not interfere in the least with the full power of the surroundings which are subsequently applied. Thus the larvæ of these experiments began to hatch on June 29th, and were kept in green surroundings until July 9th or 10th, when the dark environments were substituted. But the earlier green surroundings probably did not diminish the influence of the later environment in any instance, except perhaps the single green larva in I. The same conclusions are to be gained by a study of nearly all the species experimented with, for the environments were very rarely applied immediately after hatching.

And this is what we should expect from the habits of the larvæ, which always rest on the leaves during the earliest stages. It is probable that the colours of the mature larvæ are decided when they abandon this habit, and first come to rest on the twigs. Too early susceptibility would render all larvæ green.

We may therefore conclude that the time of effective susceptibility lies somewhere within the second and third stages of larval life, and perhaps in the third rather than the second.

A. Dark Surroundings (in addition to the necessary green leaves of the food-plant).

1. *Dark Objects which are natural to the Larvæ.*

Experiments I.—VII.

I.	II.	III.	IV.	V.	VI.	VII.
Lamp-shade. *Height*, 204 mm.; *approximate capacity*, 1900 cc.	Cylinder. *Height*, 175 mm.; *internal diameter*, 82 mm.; *approximate capacity*, 900 cc.	Lamp-shade. *Height*, 168 mm.; *approximate capacity*, 1000 cc.	Cylinder. *Height*, 176 mm.; *internal diameter*, 79·5 mm.; *approximate capacity*, 950 cc. The cylinder bulged slightly, thus increasing capacity.	Cylinder. *Height*, 185 mm.; *internal diameter*, 82 mm.; *approximate capacity*, 1000 cc.	Lamp-shade. *Height*, 127 mm.; *approximate capacity*, 750 cc.	Cylinder. *Height*, 176 mm.; *internal diameter*, 84 mm.; *approximate capacity*, 1000 cc.
Large numbers of very black rough twigs, chiefly of *Quercus cerris*, were intermixed with and heaped round the leaves.	Large numbers of lightish brown dead twigs of some species of *Salix* intermixed as in I.: the twigs were smooth.	Large numbers of reddish brown fresh twigs of *Salix rubra*, stripped of their leaves, were similarly intermixed. In a short time they became blackish.	Similar to III., except that the twigs became blackish even sooner.	Large numbers of the red-and-green stalks and stems of *Spiræa ulmaria*, stripped of their leaves, were similarly intermixed. These also soon became blackish and mouldy	Many light brown, dead ivy leaves similarly intermixed. The stalks of these leaves had been removed.	Many red leaves of *Mahonia aquifolia* were similarly intermixed. The brown spots and edges were cut off when present, but the leaves soon became blackish and mouldy.
July 9.—35 young larvæ introduced from "first stock," having been in green surroundings previously, although the leaves had lately become somewhat withered.	*July* 10.—11 young larvæ introduced, as in I.	*July* 9.—17 young larvæ introduced, as in I.	*July* 10.—18 young larvæ introduced, as in I.	*July* 10.—17 young larvæ introduced, as in I.	*July* 10.—12 young larvæ introduced, as in I.	*July* 10.—20 young larvæ introduced, as in I.
	July 17.—Mostly brown.	*July* 17.—Most of the twigs were becoming black.	*July* 17.—Twigs beginning to turn black.	*July* 17.—Mostly brown.	*July* 17.—Mostly green.	
		July 19.—17 larvæ living. The usual length was 17·0 mm. 12 green or greenish, 5 brown. The larvæ afforded a curious contrast with IV. The twigs were becoming black, but not quite so much so as in IV.	*July* 19.—18 alive: 13 brown, many darkish, 5 green or greenish. Only 1 large larva (about 17·0 mm.) was bright green. The twigs were becoming very black.			

July 27.—34 alive : 32 brown, 1 intermediate, 1 bright green. The latter was the largest, and changing last skin ; the others small in last stage but one.	*July* 27.—11 alive; all small in last stage but one, and all brown, of a shade which matches the twigs, except that it is rather darker. 3 removed to XXVII., being placed on green leaves to test whether a further change is now possible.	*July* 27.—16 alive : 7 green, 4 brown, 5 intermediate. Many of the larvæ were changing the last skin; they nearly always rested on twigs. The latter were now very dark.	*July* 27.— 11 brown, 5 intermediate, 2 green. The largest were changing the last skin, but they were mostly much smaller.	*July* 26.— 12 brown, 2 green, 3 intermediate.	*July* 23.— 6 brown, 6 green.	*July* 23.— 18 Brown and brownish, 2 greenish.
Aug. 3.—32 alive : 1 changing last skin and chocolate-brown, the others in last stage, 1 bright green, 1 dark grey, 29 intensely black, exactly like the black twigs. The green larva was the only one nearly mature; the others small in the last stage. The green larva and a black one selected for painting.	*August* 3—13.—Frequently examined ; all remained the same rich brown, almost exactly matching the brown twigs, 2 selected for figuring.	*Aug.* 5.— 5 distinct green (rather dullish, with pronounced dorsal line, tending in some to spread downwards on the anterior part of each segment. 3 greenish intermediate, 2 brownish ditto, 5 deep brown, 1 blackish.	*Aug.* 1.—*In last stage :* 12 dark brown. *Changing last skin :* 1 green, 1 greenish intermediate. *Last stage but one :* 1 chocolate-brown, 1 light brown, 1 greenish brown, 1 intermediate. *Aug.* 13.—Mostly pupating. 1 green, 1 intermediate, 1 dark. Others had died.	*Aug.* 13.— 3 intermediate, 8 dark greyish forms (not very dark).	*July* 30.—All in last stage. 9 brown, 1 green, 2 intermediate. *Aug.* 5.—Nearly mature. 1 bright green (brown dorsal line) 1 brownish intermediate, 10 light brown, and harmonising well with ivy leaves, being marked by a network of dark and light greys ; 1 was rather a rich brown, a colour also present on some of the leaves. 1 of the former was selected for painting.	*Aug.* 1.— *Last stage :* 14 brown, 1 intermediate. *Changing last skin :* 3 brown. *Last stage but one :* 1 brown. *Changing last skin but one :* 1 brown. *Aug.* 13.—Many pupating. 2 greenish intermediate 2 intermediate, 3 brownish intermediate, 13 dark, These results were approximate, because of the changes of colour before pupation. The larvæ had been probably somewhat darker.

Results (A. Dark Surroundings, &c.).

The green larva is represented Pl. XIV., fig. 9, and the dark one fig. 10. Both are shown upon the dark twigs of *Quercus cerris*, chiefly made use of in this experiment. The fact that the one exception was the largest larva on July 27, and also when painted about Aug. 5 (compare sizes of figs. 9 and 10), seems to indicate that the period of keenest susceptibility had been already passed through in its case on July 9, although not in that of the remaining larvæ. But this larva was also probably especially predisposed towards the influence of green in the surroundings, like the single green larva in Experiment II., 1889.	These results were as marked as those of I., and there was no exception here. The two larvæ figured about August 5 are shown in Pl. XIV., figs. 11 and 12. One (fig. 11) is a somewhat darker brown, and the other (fig. 12) rather lighter and greyer; but the difference is small, and represented the most extreme divergence met with in this experiment. The colour of the twigs used in the surroundings is shown in these two figures. Compare fig. 13, which shows the effect of removing 3 of the larvæ into green surroundings from July 27 until Aug. 10, when one was painted. It is rather lighter in tint, but the effect of green surroundings during the last stage, and most of the last but one, is very insignificant.	The comparison between III. and IV. is very interesting. It is evident that the change in colour of the twigs was taking place about the critical period in larval life, when susceptibility is keenest, and hence the twigs darkening rather more rapidly in IV. its larvæ are much darker as a whole, especially at first (July 19). Afterwards the gradual influence of the darkened twigs acting over a period of less susceptibility, brought the two results a little nearer together, but they remained very different at the end. The dark larvæ were not like those of I. or II., but more resembled their own peculiar environment.	These larvæ harmonised very well with the dark grey mouldy stems which formed their environment.	It has been pointed out above that these larvæ harmonised very well with the brown ivy leaves. A typical specimen was figured about Aug. 5, and is shown in Pl. XIV., fig. 14, where the appearance of the ivy leaves is indicated by one example.	These larvæ were not black, like those in I., but were dark forms, resembling the blackish mouldy leaves. The normal dark surroundings of this species are made up by twigs and not leaves, and hence we find that in this experiment, and in VI., that exceptions occur in greater proportion than when the more normal dark environment is supplied. This is probably due to the larvæ chiefly resting on dark twigs when they are present, but not seeking the dark leaves so exclusively.

2. *Artificial Dark Surroundings.*

Experiments VIII. and IX.

VIII.	IX.
Cylinder. *Height* . . . . 182 mm. *Interm. diam.* . . 83 mm. *Approx. capacity* . 1000 cc.	Lamp-shade. *Height* . . . . 164 mm. *Approx. capacity* . 1300 cc.
Smooth stripped twigs of *Salix rubra* and other species of *Salix* were enamelled black, and intermixed with and placed round the food-plant.	Rough twigs chiefly of *Quercus cerris* and elm were enamelled with black, and intermixed with and placed round the food-plant.
July 16.—10 introduced from the "second stock," having been previously in green surroundings, in darkness by day, and illuminated by a lamp at night. July 25.—Length about 24·0 mm. 7 brown, 3 green, but the latter not bright. Aug. 1. — 10 all brown, although some of them not very dark. Aug. 13.—1 had pupated, and 1 was missing. 5 *intermediate* or *lightish brown* (they had changed in colour before pupating). 3 *dark*.	July 14. — 10 young larvæ introduced from "first stock" (green leaves and shoots, which became brown towards the end). Aug. 12. — 1 *green* (pupating), 1 *intermediate*, 1 *light chocolate-brown*, 7 *dark brown* (5 pupating).

These results harmonize with those of black-paper covered sticks in the case of *R. cratægata* (see p. 324), although probably for a different reason. The artificially darkened surroundings did not seem to produce nearly so strong an effect as those which are natural to the larvæ. At the same time, the larvæ were subject to different conditions for a considerable part of their earlier life, and these probably produced effects which endured till maturity in several instances, especially in IX. It would be well to repeat these experiments, employing similar environments for the whole larval life, and again to make use of black-paper covered sticks, which were found to exercise a very strong influence on this species in 1889 (see p. 331).

3. *Dark Surroundings near the Larvæ, but not actually in contact.*

EXPERIMENT X.

X.

Cylinder: *Height*, 190 mm.; *interm. diam.*, 26·5 mm.; *approx. capacity*, 110 cc.

In this tall narrow cylinder only green leaves and shoots of food-plant were present, but outside it many twigs, as in I., were placed.

July 10. — 12 young larvæ introduced from the "first stock."

July 25.—Length about 24·0 mm. 4 *green*, 2 *intermediate*, 6 *brown*.

Aug. 1. — All but 1 in last stage; 3 *green* (1 changing last skin), 2 *greenish intermediate*, 2 *light brown*, 5 *dark brown*.

Aug. 5.—All in last stage; 3 *green* (rather dull), 2 *greenish intermediate*, 1 *very light brown*, 1 *very light grey*, 4 *deep brown* (1 very dark, 1 dead), 1 *very dark blackish grey*.

The criticism made on the analogous experiment with the 1889 larvæ (see p. 334) holds in this case. The effect of crowding comes out so clearly in some of the green surroundings (see Experiments XII. and XIII.), that it will be necessary to repeat this experiment, including very few larvæ in each cylinder, and making comparison experiments with the light dimmed by objects other than dark twigs. Until this is done, there will be no reason for believing that a larva is affected by any twigs except those with which it is in contact, or at any rate immediately surrounded. It would be interesting also to make use of dark cylinders enclosed in glass tubes of varying thickness.

B. GREEN SURROUNDINGS.

1. *Green Surroundings which are natural to the Larvæ.*

(*See Table, page* 347.)

The strong susceptibility to green surroundings in the absence of darker colours is very clearly brought out in these experiments, but also the much greater susceptibility to brown, so that when the larvæ were crowded, as they were in XII. and XIII., in cases with only half the capacity of XI. and XIV., they were strongly affected by one another's colours, which are always brown in the earlier stages. The light brown larvæ thus produced much resembled those from Experiment VI., one of which is shown in Plate XIV., fig. 14.

XI. Lamp-shade. *Height* . . 165 mm. *Approx. cap.* 1350 cc.	XII. Lamp-shade. *Height* . . 131 mm. *Approx. cap.* 650 cc.	XIII. Lamp-shade. *Height* . . 130 mm. *Approx. cap.* 800 cc.	XIV. Lamp-shade. *Height* . . 163 mm. *Approx. cap.* 1300 cc.
Green leaves and shoots of *Populus nigra* alone.	As in XI.	As in XI.	As in XI., except that abundant golden green, smooth, stripped twigs of *Salix viminalis* were intermixed. These retained their colour a long time, and only became a light greenish brown when a change eventually occurred, but the larvæ had then ceased to be sensitive.
July 9. — 20 young larvæ introduced from the "first stock," having been on the same surroundings with many others since hatching, & the leaves having become rather withered.	*July* 10.—20 young larvæ introduced; hitherto as in XI. *July* 17. — 18 alive; for the most part they remained brown.	*July* 10.—20 young larvæ introduced as in XI.	*July* 10.—40 young larvæ introduced as in XI. *July* 16. — 6 larvæ removed to put in XXXIV. *July* 19.—33 counted, of which 30 green or greenish (mostly former), & 3 brownish (not dark), & of these 1 quite small. Usual length 17·0 mm.
July 21. — Length from 15·0 to 20·0 mm. 12 larvæ green, 1 ,, greenish, 7 ,, brown, but only 1 of them darkish brown.	*July* 23.—17 alive; 14 brown, 3 green.	July 23.—20 alive: 8 brown, 12 green or greenish.	*July* 26. — 33 alive; all bright green except 1 small larva, which is intermediate. 4 just before changing last skin were removed to XXVI. to test whether any further change is now possible.
July 30.—20 alive. *Bright green*: 11 in last stage, 6 changing last skin 1 last stage but one. *Intermediate*, perhaps greenish: 1 changing last skin. *Very light brown*, perhaps intermediate: 1 (stage unnoted, probably young).	*July* 30. *Bright green*: 1 in last stage but one *Greenish*: 1 in last stage, 1 changing last skin. *Light brown*: 11 in last stage, 2 ,, but one 1 changing last skin.	*Aug.* 1. *Bright green*: 3 in last stage. *Greenish*: 6 in last stage, 1 changing last skin *Brownish intermediate*: 1 in last stage but one *Light brown*: 8 in last stage, 1 changing last skin	*July* 31.—All bright green: *Last stage* . . . 24 *Changing last skin* 3 *Last stage but one* 2 1 of the 2 last was removed to XXVI., being added to the 4 removed July 26.
Aug. 7.—All in last stage, and many pupating. All bright green, 11 without the brown dorsal stripe, or with it very faint, 8 with it distinct, the latter being generally the smaller larvæ.	*Aug.* 7. — All in last stage: 2 *bright green* (1 with and 1 without dorsal stripe). 2 *greyish intermediate* 13 *light brown*, like the 7 of XIII. and the 10 of VI.	*Aug.* 5.—In last stage. 3 *bright green* (1 small), 6 *dull but distinct green* (marked brown dorsal line), 1 *greenish intermediate*, 1 *brownish intermediate*, 7 *light brown* (1 rather darker than others), 1 *rich brown* (small), changing last skin 1 *intermediate*. The 7 light brown much resembled the 10 of VI.	*Aug.* 7.—All in last stage: 24 *bright green*, without brown dorsal stripe or with it very faint (most pupating), 4 *light green*, with dorsal line distinct (all these small in stage).

The larvæ of XIV. were much more crowded than those of XI., but became equally green, or perhaps even brighter. I attribute this to the presence of the golden-green twigs of *Salix viminalis* upon which the larvæ rested, and which influenced them strongly. We see this when we compare the rates at which the effects were manifested in XI. and XIV. Thus XIV. were far more strongly influenced by July 19 and 26 than XI. by July 21 and 30 respectively. The larvæ manifest a strong tendency to rest by day on anything twig-like, greatly preferring it to the leaves. When the latter are offered alone they frequently rest on each other, and hence their progress towards greenness is retarded or even arrested if they are sufficiently crowded.

The result of the transference of green larvæ from XIV. to dark surroundings (XXVI.) for the whole of the last stage, and in one case for most of the last stage but one also, showed that there was no power of further change. No effects at all were produced by the transference. This supports the result of the converse experiment already described (see p. 344, Expt. II.). And yet the dark surroundings to which these larvæ were removed had every opportunity of influencing them, if this were possible; for the larvæ almost invariably rested on the dark twigs with which their colours were in such marked contrast.

2. *Artificial Green Surroundings.*

(*See Table, page* 349.)

Omitting XV., the larvæ of which may have been affected pathologically by the green pigment, the other experiments show that the larvæ are affected in the direction of green, but not nearly so strongly as when the natural green surroundings are employed. The effects of the dark green enamel were very similar to those of the green leaves and shoots when the larvæ are crowded (Experiments XII. and XIII.). It is probable that the quality of the green light was less effective than that reflected from leaves and shoots: this will be considered later on (see Conclusions). The lighter green enamel (XVIII.) produced much stronger effects in the direction of green, but not equal to those of natural surroundings when the larvæ are uncrowded (XI. and XIV.). It would, however, be well to repeat the experiment over a longer period of larval life. Stronger effects would probably be witnessed, especially under the conditions of XVIII.

2. *Artificial Green Surroundings.*

EXPERIMENTS XV.—XVIII.

XV.	XVI.	XVII.	XVIII.
Cylinder. *Height* . . 179 mm. *Internal diam.* 71 mm. *Approx. cap.* 700 cc. Bright green paper spills intermixed with food-plant.	Lamp-shade. *Height* . . 166 mm. *Approx. cap.* 1200 cc. Rough twigs, chiefly of *Quercus cerris* and elm, enamelled dark green, were intermixed.	Lamp-shade. *Height* . . 109 mm. *Approx. cap.* 700 cc. Smooth twigs of *Salix* enamelled dark green, as in XVI., were intermixed.	Lamp-shade. *Height* . . 133 mm. *Approx. cap.* 700 cc. Twigs, chiefly rough, were enamelled light green and intermixed.
July 9. — 8 young larvæ introduced from "first stock," having been in green surroundings, the leaves becoming rather brown shortly before this date.	*July* 14.—10 young larvæ introduced as in XV.	*July* 16. — 8 introduced from "second stock," having been previously in green surroundings, in darkness by day, and illuminated by a lamp at night.	*July* 16. — 10 introduced as in XVII.
July 23.—More green spills added; only 4 larvæ alive; all light brown.	....	*July* 25. 1 green, 1 greenish, 1 intermediate, 5 brown.	*July* 25. 3 green, 2 intermediate, 5 brown (not dark).
July 31. — All large in last stage but one: 3 greenish, 1 light brown. 2 were resting on spills, 2 on leaves.	*July* 30. 6 *dark brown*, all at beginning of last stage, 3 *green* (not very bright), 2 at beginning of last stage, 1 changing last skin. 1 *intermediate*, changing last skin.	....	*July* 31. *Last stage:* 2 bright green, 4 dull green, 2 darkish brown. *Last stage but one:* 1 dull green, 1 intermediate.
Aug. 5.—All 4 rather small in last stage: 2 *brownish green.* 1 *intermediate.* 1 *light grey.*	*Aug.* 5. — All in last stage: 2 *bright green* (dorsal band distinct, & in 1 tending to spread downwards), 2 *intermediate*, 3 *greyish brown* (1 light), 3 *deep brown.* Not a great difference between the dark forms; none of them very dark.	*Aug.* 7.—All in last stage: 1 *bright green* (faint dorsal line), 1 *greenish intermediate*, 6 *grey*, like the 10 in VI., only darker as a whole, although with much individual difference.	*Aug.* 5.—3 larvæ had ceased feeding—2 green and 1 brown. 7 in last stage: 5 *green* (1 small), 1 *intermediate*, 1 *light brown.* All the green larvæ wer rather dull, with pronounced brown dorsal line.
Aug. 12.—All dead.	*Aug.* 12. 2 *green*, 3 *intermediate*, 5 *dark* (although not very dark).		

C. Dark and Green Surroundings in Dim Light.

Experiments XIX.—XXIII.

XIX.	XX.	XXI.	XXII.	XXIII.
Lamp-shade. *Height* . . . 163 mm. *Approx. cap.* . 1000 cc. Kept in darkness by day, and illuminated by small paraffin lamp at night (until Aug. 3rd, when exposed to ordinary conditions). Dark twigs were added July 16.	Lamp-shade. *Height* . . . 166 mm. *Approx. cap.* . 1350 cc. Similar to XIX., except that red-and-green stripped stems of dock or sorrel were added July 16. These became darker, but not blackish, like the *Spiræa*, &c.	Lamp-shade. *Height* . . . 131 mm. *Approx. cap.* . 800 cc. Similar conditions of illumination, but surroundings green (leaves & shoots alone of *Populus nigra*).	Lamp-shade. *Height* . . . 129 mm. *Approx. cap.* . 650 cc. Similar to XIX., except that the larvæ were separated from the "second stock" at a later date (July 16). Dark twigs added July 16.	Cylinder. *Height* . . . 124 mm. *Internal diam.* 67 mm. *Approx. cap.* . 450 cc. Similar to XXII., except that the surroundings remained green, as in XXI.
July 8. — 26 introduced from "second stock," having been subject to the conditions described above from the time of hatching. *July* 19. — Many were green and greenish. *July* 26.—Many of them 32·0 mm. long, others smaller: 6 green (dull), 1 intermediate, 19 brown.	*July* 8. — 25 introduced, as in XIX. *July* 19.—25 alive. *July* 26. — 24 alive; the largest about 32·0 mm. long, 2 just entered last stage: 1 green, 4 intermediate, 19 brown.	*July* 8. — 25 introduced, as in XIX. *July* 26.—Many of them 32·0 mm. long, others smaller: 6 green (dull), 2 intermediate, 16 brown. Hence 24 alive.	*July* 16. — 9 introduced, as in XIX.	*July* 16. — 9 introduced, as in XIX.
. . . .	*July* 30.—*Last stage:* 2 rather light brown, 21 dark brown. *Last stage but one:* 1 intermediate.	. . . .	*July* 30.—All dark brown: 6 in last stage, 2 ,, but one, 1 changing last skin.	*July* 30.— 8 *brown:* 4 in last stage, 1 ,, but one, 3 changing last skin. 1 *intermediate*, changing last skin.
Aug. 7.—All in last stage, and all dark blackish forms, darker than XX., and much darker than XXI., although not nearly attaining the deep blackness of I. Many were pupating.	*Aug.* 7.—All in last stage, and all dark forms, distinctly darker than XXI., with a deep brown tinge about all of them. Many were pupating.	*Aug.* 7.—All in last stage: 2 *greenish intermediate*, 22 *brown*, not very dark forms, various shades of brown and grey. Many were pupating.	*Aug.* 7.—All in last stage, and resembling XIX., being dark blackish forms, darker than XX. and much darker than XXI., although not nearly attaining the deep blackness of I. Many were pupating.	*Aug.* 5.—All mature and very uniform, being darkish grey forms,—not very dark. One larva was rich brown, intermixed with grey. Distinctly lighter than XXII. *Aug.* 13.—All 9 still dark, only 2 remained feeding.

C. Dark and Green Surroundings in Dim Light.

(*See Table, page* 350.)

These experiments were conducted with the object of investigating the relation between the habits of the larvæ as regards resting and feeding, and the external conditions as regards light. In this respect I did not come to a conclusion; but the experiments have proved very valuable in another way,—in testing the effect of dim light upon the colour-relation between larvæ and their surroundings. The effect is very clear, and conclusively proves that light is the agency which influences the larvæ. For, with this dim illumination, neither green nor (probably) even dark surroundings produce their full effect, the influence of the former naturally being diminished far more than that of the latter. Thus green surroundings continued, in this case, for the whole of larval life (XXI. and XXIII.) failed to produce a single green larva, only 2 out of 33 being greenish intermediate. It must be remembered, however, that XXI. was much crowded, as were the larvæ of XXIII. previous to July 16. On the other hand, the dark twigs in XIX. and XXII. produced very different effects from those of I., where, however, they were added 7 days earlier. Although the effects are diminished, they are not altogether absent even in the case of the green surroundings, for we find that the larvæ exposed to the latter (XXI. and XXIII.) are the lightest, those exposed to dark twigs (XIX. and XXII.) are the darkest, and those exposed to the stems of dock which became dark brownish (XX.) are intermediate. When we compare these results with those of the next experiments, in which dark and green surroundings in darkness produced the same effect on the larvæ, it becomes clear that light is the agency by which the colour-changes are directly, or more probably indirectly, brought about.

D. Dark and Green Surroundings in Darkness.

Experiments XXIV. and XXV.

XXIV.	XXV.
Lamp-shade. *Height*, 132 mm.; *approximate capacity*, 800 cc.	Lamp-shade. *Height*, 129·5 mm.; *approximate capacity*, 750 cc.
Kept in same illumination as XIX.—XXIII. from hatching until July 9. From July 9 to Aug. 3 kept in total darkness, except when fed and when XIX.—XXIII. were being shifted from light to darkness, and *vice versâ*, every 24 hours. Green surroundings as in XXIII., &c.	As in XXIV., except that abundant dark twigs were added July 16.
July 9.—25 larvæ arranged in is cylinder.	*July* 9.—25 larvæ introduced, as in XXIV.

XXIV.

Lamp-shade. *Height*, 132 mm.; *approximate capacity*, 800 cc.

July 20.—Many about 20·0 mm. long; others smaller.
2 green,
7 greenish,
16 brown.

July 26.—The largest about 32·0 mm. long.
4 green,
2 intermediate,
19 brown.

Aug. 7.—All in last stage, and all dark,—grey, brown, and blackish larvæ being intermixed. Although dark, none of them approached the results of I.

XXV.

Lamp-shade. *Height*, 129·5 mm.; *approximate capacity*, 750 cc.

July 20.—Same size as XXIV.
6 green,
7 greenish,
12 brown.

July 26.—
2 green,
7 intermediate,
16 brown.

Aug. 7.—All in last stage, and similar to XXIV. It was impossible to assert that these were any darker than the latter; the two lots were as nearly as possible the same.

The significance of these results has been pointed out already (see p. 351).

It is interesting to note that the larvæ varied greatly; this was also the case in some of the larvæ exposed to dim light (XXI.), while others were very uniform (XX., XXIII.).

E. Transference Experiments.

Experiments XXVI. and XXVII.

XXVI.

First contained in XIV.; then in cylinder.
Height, 176 mm.
Internal diameter, 71 mm.
Approximate capacity, 700 cc.
Transferred from green to dark surroundings for the last stage.

July 26.—4 green larvæ about 32·0 mm. long, just before changing their last skins, transferred from XIV. to another cylinder with abundant dark twigs intermixed.

July 27.—All but 1 were changing skins, and all were resting on the dark twigs.

July 30.—Same; all on brown twigs, and as bright green as ever.

July 31.—Same; still resting on brown twigs. A fifth bright green larva, small in last stage but one, transferred from XIV. to this cylinder.

Aug. 1.—All resting on brown twigs, and all bright green.

Aug. 5.—The 4 larvæ transferred July 26 had ceased feeding, remaining bright green, with a faint dorsal line. The 1 small larva transferred July 31 was changing last skin, and was bright green, with distinct dorsal line. There was no further change.

XXVII.

First contained in II.; then in cylinder.
Height, 86 mm.
Internal diameter, 61 mm.
Approximate capacity, 250 cc.
Transferred from dark to green surroundings for last stage, and part of last but one.

July 27.—3 brown larvæ, about 24·0 mm. long, transferred from II., where they had been subjected to brown surroundings, to green leaves and twigs alone of food-plant.

July 31.—2 changing last skin, 1 at beginning of last stage; still brown.

Aug. 5.—The 3 larvæ were now more than half-grown in last stage, and had become rather lighter than those remaining in II. The most changed was painted.

The results of these experiments have been described under II. and XIV. respectively (see pp. 344 and 348).

It is interesting to note that the darkening of a larva which has become green appears to be more difficult than the converse change. Thus the effects, if any, in XXVI. were confined to the dorsal area (even in the larva transferred on July 31), whereas the pigment in XXVII. had become somewhat lighter over the whole surface.

F. White Surroundings.

(*See Table, page* 354.)

The faintly greenish white larva is shown in Plate XIV., fig. 15; the faintly brownish in fig. 16. Reference to these figures will show how completely the white dominates the tendency to other colours; and, as shown above, there was no such tendency in most of the larvæ in XXVIII.

The less marked effects witnessed in XXIX. and XXX. were probably due to the facts that the experiments began later, and that the enamelled surface was less congenial to the larvæ than the paper. But it would be well to repeat these experiments. It must be remembered, too, that the sticks in XXX. were not so white as the others.

G. Surroundings of other Colours.

(*See Table, page* 355.)

The influence of blue (XXXI. and XXXII.) is evidently strongly in the direction of dark forms. The uniform purplish brown colour of all the larvæ in XXXI. must be something more than a coincidence. It is clear that the blue not only tended to produce dark larvæ, but dark larvæ of a certain kind. At the same time the larvæ did not resemble the blue spills, but were such as would have been protected on dark purplish brown twigs. Some quality in the light reflected from such twigs would cause the larval adjustment, and this experiment suggests that the proportion of blue rays may be the effective stimulus which causes the larvæ to assume the appropriate shade of brown. The appearance of these larvæ is well shown in Plate XIV., fig. 17, where the

F. White Surroundings.

Experiments XXVIII.—XXX.

XXVIII. Cylinder. *Height* . . 149 mm. *Intern. diam.* 71 mm. *Approx. cap.* 600 cc. Many white paper spills intermixed with and surrounding food-plant.	XXIX. Lamp-shade. *Height* . . 165 mm. *Approx. cap.* 1300 cc. Many rough twigs, chiefly of *Quercus cerris* and elm, were enamelled twice with white, and intermixed.	XXX. Lamp-shade. *Height* . . 147 mm. *Approx. cap.* 550 cc. Similar to XXIX., except that twigs were only enamelled once, & hence were not so brilliantly white.
July 11. — 10 young larvæ introduced from "first stock," having been previously on green leaves and twigs alone, which had become somewhat brown by July 11. *July* 21. — Larvæ 22·0 mm. long: 3 bright green, 6 greenish, 1 light brown. Some of the larvæ had a very whitish appearance; this was noticed some days previously.	*July* 14. — 10 young larvæ introduced, as in XXVIII.	*July* 16.—9 introduced from the "second stock," having been on green surroundings, in darkness by day, and lamp-light at night.
July 23. — More spills added.	*July* 25.— 5 green, 1 greenish, 4 brown (not dark).	*July* 25.—9 alive: 7 green, 2 greenish.
July 30. — All in last stage; all resting on the spills: 8 *very whitish* & opaque-looking, 1 *green*, 1 *brownish* (small in last stage). *Aug.* 3.—Carefully compared; all 10 nearly mature, and extremely white and opaque. The results were very uniform, although 2 were faintly greenish and 1 faintly brownish, but these tints were nearly hidden in the predominant tendency towards white. One of each was selected for painting.	*Aug.* 7.—All last stage: 4 *bright green* (dorsal line very distinct on 1, faint on 2, overspread with grey on 1), 4 *whitish*, 2 *very light grey*, inclining to whitish. The whitish larvæ were duller and more inclining to other colours (greenish, brownish or yellowish) than those of XXVIII. They were, however, quite distinct opaque whitish forms.	*Aug.* 7. — All in last stage: 4 *bright green* (3 with distinct dorsal line, 1 tending to be overspread with grey), 4 *whitish* (duller than XXIX.), 1 *light brown*, like the 10 larvæ in VI.

G. Surroundings of other Colours.

Experiments XXXI.—XXXIV.

XXXI.	XXXII.	XXXIII.	XXXIV.
Lamp-shade. *Height* . . 131 mm. *Approx. cap.* 700 cc. Many dark blue paper spills intermixed with food-plant and surrounding it.	Cylinder. *Height* . . 158 mm. *Internal diam.* 71 mm. *Approx. cap.* 650 cc. Similar to XXXI., except that the blue, although pronounced, was not so deep in tint.	Lamp-shade. *Height* . . 133 mm. *Approx. cap.* 700 cc. Many deep orange paper spills and pieces of paper similarly intermixed.	Cylinder. *Height* . . 180 mm. *Internal diam.* 82 mm. *Approx. cap.* 1000 cc. Many smooth twigs of *Salix* enamelled deep orange were similarly intermixed.
July 10.—11 young larvæ introduced from the "first stock," having been previously in green surroundings, which had become somewhat dark towards this date.	*July* 10.—11 young larvæ introduced, as in XXXI.	*July* 9.—12 young larvæ introduced, as in XXXI.	*July* 14.—4 young larvæ introduced, as in XXXI.
July 21.—10 alive: 9 brown, many dark; 1 greenish, the largest. The general length was about 19·0 mm. *July* 23.—More spills added. *July* 31.—All 10 in last stage, and all very dark. They nearly always rest on the spills.	*July* 21.—10 alive: 9 brown, many dark; 1 green (the largest larva). About 19·0 mm. is the usual length. *July* 23.—More blue spills added. *July* 31.— 9 small in last stage; all dark, but not so dark as in XXXI. 1 green. not bright, but with much brown on back, and yellow spots distinct on side and beneath. This is the largest, and almost mature. The larvæ nearly always rest on the spills.	*July* 19.—Larger larvæ about 17·0 mm. long. 1 darkish brown, 11 varying from greenish to brownish green. No bright green larvæ. *July* 23.—More orange spills added. 1 brown, 11 green, some of them greenish. *July* 31.—12 all green, although many were not the brightest green. They were nearly always found resting on the orange paper.	*July* 16.—6 more added from XIV. *July* 25.— 7 green, 1 greenish, 1 intermediate, 1 brown.
Aug. 3.—Uniformly very dark purplish brown, with hardly any individual differences. The 10 larvæ were nearly mature. A larva was selected for painting. *Aug.* 12.—Only one feeding. All remained very dark, as before.	*Aug.* 5.—All in last stage, and about mature. 1 *greenish intermediate*, 1 *lightish grey*, 4 *deep rich brown*, } about equally dark. 4 *blackish.* } These larvæ were very dark, although not nearly so much so as those of XXXI. *Aug.* 13.—All pupating.	*Aug.* 12.—Many pupating, and all 12 mature. All bright green, generally with but slight dorsal line.	*Aug.* 5.—All last stage, nearly mature. 7 *bright green* (only 1 with dorsal line distinct), 2 *intermediate*, 1 *light brown.*

purplish larva is represented on a spill of the dark blue colour employed. The effects of lighter blue (XXXII.) were far less uniform. It may be that the blue rays must come from a surface of a certain depth of colour in order to produce the effect seen in XXXI.

Orange surroundings, on the other hand (XXXIII. and XXXIV.), tend to produce typical green larvæ, although the effect of orange paper was much stronger than that of orange enamel. The larvæ were, however, exposed to the latter for a shorter time, and probably found it a less congenial surface to rest upon.

Here, too, when an artificial colour entirely different from anything in the normal surroundings of the species produces exactly the same effect as a totally different appearance in the natural environment, the most probable view is that there is some common quality in the reflected light, and that this is the effective stimulus. If there were any evidence for pathological change or abnormal development of any kind, the argument would not hold; but the larvæ reared among orange spills and sticks appeared to be as healthy, and in every way as normal, as those reared among the green leaves and shoots, which produce the same result. Nor is it at all probable that the results are merely due to the quantity of reflected light rather than its quality. Thus the greater amount of light reflected from white paper does not make the larvæ greener than orange paper, but utterly different in appearance.

These considerations will be brought side by side with those derived from the experiments on pupæ in the Conclusions at the end of the paper, where the spectroscopic composition of the light reflected from the backgrounds will be described, together with its effect upon the various species employed.

Comparison with the earlier experiments on the pupæ of *Pieris rapæ* and *P. brassicæ* strengthens this conclusion; for I have shown (Phil. Trans. Roy. Soc., vol. 178 (1887), B, pp. 429—432) that in both these species the same orange paper employed in XXXIII. and the same blue employed in XXXI., produced green and dark pupæ respectively. On p. 431 the extent in the spectrum of the rays which were chiefly reflected from these colours is represented in a diagram, and it is shown to be probable that the rays which check the formation of true pigment, and so reveal the more deeply placed green, lie between a wave-length of $\frac{57}{100000}$ and $\frac{60}{100000}$ mm.; in other words, about the D line of the solar spectrum.

It will be of the greatest value to now test these conclusions by the use of coloured glass or gelatine screens. White spills or painted sticks might be employed in a large number of experiments with screens of various colours. This method has been already tried to some extent with the pupæ (see *Vanessa io* and the *Pieridæ*), but the larvæ of *A. betularia* are far more suited for the investigation, being so highly sensitive, and possessing such a wide range of possible colours and combinations of colours.

The fact that each of these artificial colours produces nothing peculiar, but only some one out of the well-known appearances which are liable to occur in the surroundings, is strongly in favour of the essentially protective significance of the change, which is thus only possible when it leads to harmony with some natural environment. The same fact holds universally throughout the species which have been proved to be susceptible, unless an exception is to be made in favour of the golden pupæ of *Vanessa urticæ*. These, however, are discussed in a later part of the paper (see Conclusions).

The Structural Cause of the varied Colours of the Larvæ of Amphidasis betularia.

This was partially investigated in 1889 (see p. 336), and was proved to be due to colour in the skin or just below it. In the present year the following method was adopted, and found to work well. The larva was stretched with its ventral line uppermost across a glass slide covering a window cut in a sheet of cork. The anterior and posterior ends of the larva extended beyond the glass, and were pinned to the cork. The body walls were then divided along the median ventral line and pinned out flat at each end, so that the section of the body passing across the glass was flat also. The latter part could be examined from above or below with the lens or a compound microscope, and the effect of removing any coloured layer was at once seen.

In such stretched and flattened larvæ the loss of the green blood made the colour rather less deep, and the same effect followed the removal of a section of the digestive tract. But I do not think any effect is produced in the normal state when the larva is less stretched, and the superficial coloured layers are therefore thicker, and when the light has to penetrate the larval skin before reaching the blood and internal organs; so that the latter cannot be highly illuminated as they were in the dissection.

In all larvæ the layer of fat between the superficial muscles and the epidermis (hypodermis) was more or less green. In green varieties it is bright green, and causes the colour of the larva, as is at once seen if a small area be removed. In some brown larvæ it is quite as green as in the green ones, but is concealed by dark pigment in the epidermis, which acts as a screen. In others the colour is developed but little, and in one dark larva examined this fat was pale yellowish green, except in the first abdominal segment, where it was as strongly coloured as in a green larva. If a little of the green fat be removed and examined under the microscope, it is seen to be opaque and bright green. It can be made thinner by pressure, and thus rendered transparent, when it appears as a pale yellowish green. High powers show that the green colouring matter (probably some derivative of chlorophyll) is contained in the oil-globules within the cells. Alcohol instantly turns the fat deep yellow, and causes the oil-globules to be compressed out of the cells, and to cohere in large yellow drops, gradually decolorised by the alcohol, which becomes itself tinged with the same colour.

The dark pigment is contained, as I have said, in the epidermis cells, which lie over this layer of fat, thus concealing the latter. In green larvæ the epidermal layer covering the green fat contains a light yellow transparent colour, appearing greenish yellow under the microscope. It dissolves out in alcohol, and is probably some chlorophyll derivative. The cuticle is colourless, except for certain small brown spots.

Intermediate larvæ are well suited for displaying both these causes of colour. These are commonly green, with a distinct wide brown dorsal stripe, which, anteriorly in each segment, passes downwards, and forms a girdle round the larva; while posteriorly the green colour forms a broader girdle, interrupted in the dorsal region by the brown stripe. If such a larva be pinned out in the manner previously described, the appearance, as seen from the internal surface, after removing the digestive tract and most of the deep part of the fat-body, is shown in Plate XIV., fig. 18, where abdominal segments 1 to 4 are represented. The tracheal system is only indicated on the left side. The anterior direction is shown by the arrow. In each segment the anterior brown band prolonged from the dorsal stripe is well shown, and here the epidermis is not underlaid by green fat, although this effect is probably in part due to the stretching. A mass of bright yellow fat lies on each side of the dorsal stripe anteriorly in each segment. This belongs to a deeper part of the fat-body *below* the muscles of the body-walls. Over the green fat which forms the posterior band in each segment, it has been already stated that the epidermis is not brown but pale yellowish in tint, and quite transparent.

It is therefore clear that the surroundings determine not only the presence or absence of true pigment in the epidermic cells, but also its constitution and therefore colour when present. And the range of possible tints and combinations is very wide, including all shades of brown and grey, passing into black on the one side and white on the other, and comprising uniform tints as well as the most complex combinations, as when these larvæ resemble the appearance of lichen. But the surroundings also determine the presence of the green colour in the superficial layer of fat. These are the results, and some quality in the light reflected from surrounding objects forms the cause, but the physiological chain which connects the two has yet to be discovered.

Direct Evidence of a Colour-relation between the Larvæ of A. betularia and their Natural Surroundings.

Nearly all the colours obtained in these experiments are well known in the field, and the others will doubtless be found if looked for on plants of the appropriate colour. Thus the white varieties, the only ones I have not seen wild, would probably be found upon food-plants with white pubescent or glaucous shoots. Such a wide power of colour-adaptation is especially necessary for a larva which feeds, like *A. betularia*, on almost any shrub or tree. For several years I have observed the correspondence between wild larvæ and their food-plants. Thus they are especially common in gardens feeding on rose, and, so far as I have observed, these are invariably green and well concealed among the abundant green shoots on which, and not on the older brown wood, they are found. I have found the same to be true of larvæ found on the green shoots of sallow and *Ribes americana*, while larvæ found on the brown branches of cherry were brown, and the same was the case with one found on apple. Two green varieties found feeding on broom were brought me by Miss Gould during the past autumn. The larvæ are very commonly beaten from birch and oak, and these are, so far as my experience goes, always dark varieties. Mr. Arthur Sidgwick, who has had a wider experience of the wild larvæ, not only agrees with this, but tells me that he always notices a difference between the dark larvæ beaten from the two trees, corresponding to the difference between the twigs on which the larvæ rest in the two cases.

The most interesting example, however, was told me by Dr. Stacey Wilson, of Birmingham, who beat the larva from a lichen-covered food-plant, and found it so exactly resembled the lichen that he thought it could not be this species at all, and was only convinced when the moth appeared. Had I known this earlier in the summer, I should have tried the effect of lichen-covered sticks. In a complex result of this kind it would be especially interesting to attempt to determine the peculiar quality in the reflected light which acts as the stimulus.

There is thus a considerable body of evidence to prove that the results obtained by breeding in confinement under certain conditions, point to the existence of a power of individual colour-adaptation which is possessed and is widely used by the wild larvæ in their natural surroundings.

C. Experiments on the Colours of Pupæ, 1887—1892.

These experiments were partly undertaken in order to confirm the results of my previous work (Phil. Trans., B., 1887, p. 311), and partly to make out further details. Professor Weismann had suggested to me that confirmation was desirable, inasmuch as the results of experiment were not uniform, but depended upon averages. I was also very anxious to investigate the pupa of *Vanessa io* as completely as that of *V. urticæ.* Considering the importance of the conclusions which seem legitimately to follow from the results of conflicting colour experiments, I was desirous of repeating these, and of devising some improved method by which the larvæ could be subjected to the conditions for the whole of the sensitive period. Coloured glass screens have also been employed in many of the experiments, especially with the *Pieridæ.* Attention was also directed to other special points, some of which came out in the course of the enquiry.

Crowding the larvæ affects the colour, and therefore the size of the receptacles becomes a matter of importance. These are described in detail at the end of the paper, and will be referred to by numbers, accompanied by a very brief description, under the experiments themselves.

Experiments upon Vanessa urticæ.

1887.

In working at these pupæ in the preceding year, I gained a very strong impression that the pupæ in darkness were, other things being equal, formed later than those in the light. If this were the case, it appeared possible that time might be an element in the production of the dark superficial pigment which prevents the golden appearance. I had concluded that this protraction of the period before pupation occurs, from the experiments on *Pieridæ,* as well as those on *Vanessidæ* (Phil. Trans., 1887, B., pp. 339 and 432), and my friend Mr. G. C. Griffiths had independently noticed the same thing with the *Pieridæ* (Trans. Ent. Soc. Lond., 1888, pp. 256, 257). I was therefore anxious to make some experiments with this special end in view, the impression I had gained being merely the incidental result of experiments intended for other purposes.

I made three such sets of experiments upon *V. urticæ* in 1887, and a brief summary of the first is given in a footnote to the paper referred to above (Phil. Trans., *l. c.*, p. 339).

Before detailing these experiments, it will be necessary to quote the description of the varieties of this pupa from my earlier paper :—

"(1) Very unusually dark, almost black; very little gold, or none.

(2) Dark normal form; dark grey, often with a slight pinkish tinge, with very little gold, or none.

(3) Light normal form; light grey, often with a pronounced pinkish tinge; more gold than (2), occasionally none.

(4) Lighter than (3); the pinkish tinge often very pronounced, and usually a large amount of gold.

(5) Very light forms; generally completely covered with gold" (Phil. Trans., B., 1887, p. 320).

It was also found convenient to subdivide the (3)s still further into dark (3)s, (3)s, and light (3)s. This arrangement will be adopted in the present paper.

Experiments 1 and 1*a*.

A small company of 44 larvæ of *Vanessa urticæ* were found at Oxford, at 7.30 p.m., July 11, 1887. They were so obviously mature that it was probable that some had already left the food-plant, and that the shock of capture would cause these remaining larvæ also to seek pupation. Their size being very uniform, they were well suited for the purposes of this enquiry.

About 10 p.m. they were offered food; the majority refused it, and wandered. These were separated, and again offered food; and it was assumed that the 29 larvæ which again refused it, had entered Stage I. of the period before pupation. They were therefore divided between the 3 receptacles described below, while the 15 which remained on the food were placed with leaves in 3 similar receptacles. The arrangements were complete about 10.45 p.m.

(*See Table, pages* 363, 364.)

Several very interesting conclusions can be derived from this table.

Bearing upon the duration of the stages before pupation :—

The observations were repeated so frequently that the beginnings of the stages can be fixed with a very small margin of error.

Dates.	Experiment 1.—Without food.			Experiment 1. a.—With food.		
	These numbers refer to detailed description of receptacles (see G, Appendix).					
	XXXI. or XLVI. Dutch leaf. Gilt box in strong light.	Similar to XLIX. Bright tin box in strong light.	I., II., or III. Black cylinder in darkness.	XXXI. or XLVI. Dutch leaf. Gilt box in strong light.	Similar to XLIX. Bright tin box in strong light.	I., II., or III. Black cylinder in darkness.
July 11, 10.45 p.m.	9 larvæ introduced.	6 larvæ introduced.	14 larvæ introduced.	2 larvæ introduced.	6 larvæ introduced.	7 larvæ introduced.
July 12, 9.15 a.m.	1 suspended, rest on roof.	All on the roof.	All on the roof.	All on food.	2 on roof, rest on food.	1 on roof, rest on food.
,, 10.30 a.m.	2 suspended (say 9.50 for 2nd larva).	Ditto.	Ditto.	Ditto.	5 have now left food (say 9.50 for 3rd, 4th, and 5th larvæ).	4 have left food (say 9.50 for 2nd, 3rd and 4th larvæ).
,, 12.20 p.m.	Ditto.	Ditto.	Ditto.	1 has left food (say 11.30).	Ditto.	5 have left food (say 11.30 for 5th larva).
,, 3. 0 p.m.	6 suspended (say 1.40 for 3rd, 4th, 5th, and 6th larvæ).	2 suspended (say 1.40 for 1st and 2nd larvæ).	2 suspended (say 1.40 for 1st and 2nd larvæ).	Both have left food (say 1.40 for 2nd larva).	2 suspended (say 1.40 for 1st and 2nd larvæ).	1 suspended (say 1.40). 5 on roof (say 1.40 for 6th larva).
,, 5. 7 p.m.	8 suspended (say 4 p.m. for 7th & 8th larvæ).	3 suspended (say 4 p.m. for 3rd larva).	4 suspended (say 4 p.m. for 3rd & 4th larvæ).	1 suspended (say 4 p.m.).	4 suspended (say 4 p.m. for 3rd & 4th larvæ).	2 suspended (say 4 p.m. for 2nd larva); all have left food (say 4 p.m. for 7th larva).
,, 8.30 p.m.	2 pupated, 1 about an hour (say 7.30), 1 a few minutes (say 8.20). Both moderately isolated on roof, and both moderately golden (5)s, the latter one being rather the more brilliant.	5 suspended (say 6.50 for 4th and 5th larvæ).	10 suspended (say 6.50 for 5th to 10th larvæ).	2 suspended (say 6.50 for 2nd larva).	5 suspended (say 6.50 for 5th larva).	4 suspended (say 6.50 for 3rd and 4th larvæ).
,, 10. 0 p.m.	Ditto.	Ditto.	11 suspended (say 9.15 for 11th larva).	Ditto.	6 suspended (say 9.15 for 6th larva).	5 suspended (say 9.15 for 5th larva).
,, 11.15 p.m.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.
,, 12 midnght.	Another pupated (say 11.40), one of a group of 6 suspended larvæ on the roof, a very light (3) brilliant.	Ditto.	12 suspended (say 11.40 for 12th larva).	Ditto.	Ditto.	Ditto.

July 13,	8. 0 a.m.	5 pupated; the others of the group of 6 on the roof mentioned above. 3 some few hours (say 4 a.m.); all (3)s with very little gilt, 2 recently (say 7.30) both normally golden (5)s.	3 pupated some few hours (say 4 a.m.), moderately crowded on roof. 2 (3)s and 1 (4) with normal gilt.	3 pupated, 2 some few hours (say 4 a.m.): a very black (1) and a very dark (3); 1 only just pupated (say 8 a.m.), and a very dark (3). All the larvæ suspended.	1 pupated recently (say 7.30), isolated on the roof; an extremely brilliant (5).	4 pupated, 2 some few hours (say 4 a.m.), 1 on roof (not crowded), a (4) with moderate gilt: 1 suspended on back, but fell to floor, a very dark (3). 1 pupated recently (say 7.30) on roof (not crowded), a (4 as above. 1 only just pupated (8 a.m.) on roof (not crowded), a (4) more silvery than golden.	2 pupated, 1 some few hours (say 4 a.m.), and a light (3), exceptionally golden: 1 recently (say 7.30), and a very light (3), exceptionally golden. All the larvæ suspended.
,,	10. 6 a.m.	The last larva is now suspended (say 9 a.m. for 9th larva).	1 pupated on roof (say 9 a.m.), moderately crowded: a (4) moderate gilt.	3 pupated: 2 only just completed change (10 a.m.), and are a very dark (3) and a (4). The 3rd pupa (say 9 a.m.) is a (3).	1 pupated (say 9 a.m.) on a leaf of food-plant; an extremely brilliant (5).	1 pupated (say 9 a.m.) on roof, not crowded, a (4) with moderate gilt.	2 pupated (say 9 a.m. for 3rd and 4th larvæ), a (1) and a (3).
,,	11.35 a.m.	Ditto.	1 pupated as above (say 10.50): a (4) little gilt.	4 pupated: 3 recently (say 11 a.m.), 2 very light (3) and 1 light (3). 1 earlier (say 10.30), and a very dark (3).		1 pupated on food-plant, probably some few hours (say 4 a.m., but very uncertain), and not noticed before: a (5), very brilliant.	No further change.
,,	12.40 p.m.	Ditto.	Ditto.	1 has pupated quite recently (say 12 noon), a (3).			1 has just pupated (12.40), a (1).
,,	1.35 p.m.	Ditto.	Ditto.	Ditto.			Ditto.
,,	2.40 p.m.	Ditto.	Ditto.	Ditto.			Ditto.
,,	3.40 p.m.	Ditto.	Ditto.	1 has pupated nearly an hour (say 3 p.m.) a (5), brilliantly golden			1 has just pupated (3.40), a very dark (3).
,,	8.30 p.m.	Ditto.	1 pupated some few hours (say 6 p.m.), as above: a light (3).	2 pupated: 1 some hours (say 6 p.m.), a light (3), & 1 quite recently (say 8 p.m.), a (2).			1 has just pupated (8.30), a dark (3).
,,	11.30 p.m.	The last larva has just (11.30) pupated, isolated on roof; a (4) with unusual gilt.					

I have previously spoken of the period before pupation as the "preparatory period," and have pointed out that it consists of three stages:—

"Stage I., in which the larva quits its food plant and hurries about, seeking for some place upon which to pupate.

Stage II., in which the larva rests motionless upon the selected surface, and towards the end of the stage spins the boss of silk for its subsequent suspension.

Stage III., in which the larva hangs suspended by its posterior claspers from a boss of silk" (Phil. Trans., 1887, B., pp. 327, 328).

If we assume that Stage I. began with the shock of capture in the case of the first three larvæ to pupate in each of the three receptacles without food, the following table indicates the beginnings and ends of all the stages and preparatory periods which could be safely fixed.

(*See Table, pages* 366, 367.)

The first point brought out by these figures is the great difference between the lengths of the stages, according as the larvæ remained upon the food-plant, or were wandering at the time the experiment began. Stating the results approximately, this difference is more clearly shown by the following arrangement:—

(*See Table* 1, *page* 370.)

It is here seen that the great difference between the length of the period before pupation in A, C, E, and B, D, F, is almost entirely due to the immensely greater duration of Stages I. and II. in the former, Stage III. being approximately the same throughout.

My former conclusions as to the lengths of the stages before pupation were chiefly founded upon experiments which resembled A, C, E, rather than the others, and hence this comparison has an important bearing on the recorded results, which were summarized as follows:— "The larvæ wander for a variable time, then rest for about 15 hours upon the surface selected for pupation, and finally hang suspended, head downwards, for about 18 hours, after which time pupation takes place" (Phil. Trans., *l.c.*, p. 438). The estimates arrived at above are much smaller, especially in the larvæ provided with food,

	Gilt boxes in strong light.										
	Without food.									With food.	
	1st larva	2nd "	3rd "	4th "	5th "	6th "	7th "	8th "	9th "	1st larva	2nd "
Length of Stages I. & II. . .	. .	14 h 20 m	18 h 10 m	. .	. .	. .	. .	. .	. .	4 h 30 m	5 h 10 m
Length of Stage III.	. .	10 h 30 m	10 h	14 h 20 m	14 h 20 m	14 h 20 m	15 h 30 m	15 h 30 m	14 h 30 m	15 h 30 m	14 h 10 m
Length of whole period before pupation	24 h	24 h 50 m	28 h 10 m	32 h 30 m ?	32 h 30 m ?	32 h 30 m ?	. .	. .	. .	20 h	19 h 20 m
Pupal colours	(5)	(5)	Very light (3), brilliant.	(3)	(3)	(3)	(5)	(5)	(4)	(5)	(5)
Average length of Stages I. and II.	Average of 2 cases, 16 h. 15 m.									Average of 2 cases, 4 h. 50 m.	
Average length of Stage III.	" 8 " 13 h. 37½ m.									" " 14 h. 50 m.	
Average length of whole period before pupation	" 3 " 25 h. 23⅓ m.									" " 19 h. 40 m.	

	Tin boxes in strong light.											
	Without food.						With food.					
	1st larva	2nd "	3rd "	4th "	5th "	6th "	1st larva	2nd "	3rd "	4th "	5th "	6th "
Length of Stages I. & II. . .	18 h 10 m	18 h 10 m	20 h 10 m	. .	. .	. .	. .	. .	6 h 10 m	6 h 10 m	9 h	. .
Length of Stage III.	14 h 20 m	14 h 20 m	12 h	14 h 10 m	16 h	. .	14 h 20 m	14 h 20 m	15 h 30 m	16 h	14 h 10 m	. .
Length of whole period before pupation	32 h 30 m	32 h 30 m	32 h 30 m	. .	. .	. .	. .	. .	21 h 40 m	22 h 10 m	23 h 10 m	. .
Pupal colours	2 (3)s 1 (4)			(4)	(4)	light (3)	1 (4) 1 very dark (3)		(4)	(4)	(4)	(5)
Average length of Stages I. and II.	Average of 3 cases, 18 h. 50 m.						Average of 3 cases, 7 h. 6⅔ m.					
Average length of Stage III.	" 5 " 14 h. 10 m.						" 5 " 14 h. 52 m.					
Average length of whole period before pupation	" 3 " 32 h. 30 m.						" 3 " 22 h. 20 m.					

	Black cylinders in darkness.																				
	Without food.														With food.						
	1st larva	2nd ,,	3rd ,,	4th ,,	5th ,,	6th ,,	7th ,,	8th ,,	9th ,,	10th ,,	11th ,,	12th ,,	13th ,,	14th ,,	1st larva	2nd ,,	3rd ,,	4th ,,	5th ,,	6th ,,	7th ,,
Length of Stages I. & II.	18 h 10 m	18 h 10 m	20 h 30 m	..	..	..	..	..	..	..	..	..	..	..	..	6 h 10 m	9 h	9 h	9 h 45 m	..	..
Length of Stage III.	14 h 20 m	14 h 20 m	16 h	17 h	15 h 10 m	15 h 10 m	16 h 10 m	16 h 10 m	16 h 10 m	16 h 10 m	14 h 45 m	15 h 20 m	..	..	14 h 20 m	15 h 30 m	14 h 10 m	14 h 10 m	15 h 25 m	..	..
Length of whole period before pupation	32 h 30 m	32 h 30 m	36 h 30 m	..	..	..	..	..	..	..	..	..	..	..	..	21 h 40 m	23 h 10 m	23 h 10 m	25 h 10 m	26 h	28 h 30 m
Pupal colours	1 (1) and 1 very dark (3)		Very dark (3)	(3)	1 (4) and 1 very dark (3)		Very dark (3)	1 light (3) 2 very light (3)			(3)	(5)	light (3)	(2)	Light (3) Very golden	Very light (3)	1 (1) and 1 (3)		(1)	Very dark (3)	Dark (3)
Average length of Stages I. and III.	Average of 3 cases, 18 h. 56⅔ m.														Average of 4 cases, 8 h. 28¾ m.						
Average length of Stage III.	,, 12 ,, 15 h. 33¾ m.														,, 5 ,, 14 h. 43 m.						
Average length of whole period before pupation	,, 3 ,, 33 h. 50 m.														,, 6 ,, 24 h. 36⅔ m.						

and the question arises as to whether these or the larvæ without food gave the more normal results.

Assuming that the power of resembling surrounding surfaces is normal to the species (and we are justified in assuming this), the extent of resemblance becomes some test of the normal condition, including duration of the preparatory stages, in which the resemblance is brought about. The pupal colours are tabulated at the end of the last analysis (pp. 366, 367), which distinctly shows that the number of exceptions is far greater among the pupæ in the receptacles without food, the larvæ of which passed through the longer preparatory stages. It becomes probable that some of the more irritable larvæ, which are so disturbed by the shock of capture that they refuse to feed, do not pass into a normal preparatory period, so far as Stages I. and II. are concerned, and, inasmuch as Stage II. is in this species the chief time of susceptibility, frequently produce pupæ which are abnormal in that they are exceptions to the usual resemblance to surroundings. If this be so, the normal susceptibility of the species must be far higher than that indicated by the results of my previous paper, in which the larvæ were generally treated as in the receptacles without food; and Stages I. and II. must be far shorter.

On the other hand, it must be remembered that the batch of 44 larvæ were probably the last of a large company, while the 15 provided with food were the last of the batch. If there is any tendency towards the shortening of the stages in the latest larvæ, these 15 would exhibit the tendency. There is, however, no evidence for the existence of such a tendency, and the fact that pupation occurred far later in certain larvæ without food than in any of those provided with it, seems to indicate that we are dealing with an abnormal protraction of the preparatory period,—the larvæ which were the first to leave the food being much the last to pupate.

Upon the whole, it is probable that the preparatory stages of the 15 larvæ are about normal, and that Stages I. and II. are made too long in my previous paper. It is true that the early stages are hurried on by the shock of capture, but they appear to be far from hurried through.

Stage III. does not seem to be affected by disturbance of the larvæ. The estimate of 18 hours must be reduced to about 15, but this latter duration was commonly noticed in the previous observations (*l. c.*, pp. 342, 347, 351, &c.).

At the same time, I should be glad for these conclusions to be tested by the observation of larger numbers, and of many companies. My previous results depended on such varied material, which, upon the whole, gave such distinct testimony in favour of longer stages, that it is possible that some of the difference may be due to the hereditary individual predispositions of the 44 larvæ observed in 1887.

Relying on the latter observations alone, we should conclude that the preparatory period varies from 20 to 24 hours, Stages I. and II. together from 5 to 9; while Stage III. has a nearly constant duration of 15 hours.

Bearing upon the lengths of preparatory stages in different conditions:—

Under any circumstances the observation has a clear bearing upon the conclusion I had previously arrived at, —that darkness protracts the stages. Whether we consider the larvæ with or without food, the results are the same: Stages I. and II. are longer in the tin box than in the gilt box, in the dark cylinder than in the tin box, and the pupal colours become darker in the same order (see preceding table, pp. 366, 367). And the difference is much clearer in the larvæ with food, which have been shown above to be, in all probability, in a more normal state. The conclusion previously arrived at was capable of two explanations: darkness might directly protract the stages, or its action might be indirect, tending towards the production of dark pupæ, and time being an element in the formation of the superficial pigment, or rather of some colourless precursor. The latter view is strongly supported by the observations here recorded; for the difference in duration is true of the tin- as compared with the gilt-box, in which, although both were in light, there was a corresponding difference in the pupal colours. Furthermore, the more marked difference, in the case of the larvæ with food, corresponded to a more marked difference of pupal colours, although unattended by any difference of illumination, as compared with the larvæ without food. All these statements will be found

TABLE 1.

	Length of Stages I. & II.	Length of Stage III.	Length of whole period before pupation.	Degrees of Pupal Colour. (1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	
Gilt box, without food...... A	16¼ hours.	13½ hours.	25½ hours.				3	1	1	4	= 9
Gilt box, with food .... B	4¾ ,,	14¾ ,,	19¾ ,,							2	= 2
Tin box, without food...... C	18¾ ,,	14¼ ,,	32½ ,,				2	1	3		= 6
Tin box, with food .... D	7 ,,	14¾ ,,	22¼ ,,			1			4	1	= 6
Black cylinder, without food E	19 ,,	15½ ,,	33¾ ,,	1	1	4	2	4	1	1	=14
Black cylinder, with food .. F	8½ ,,	14¾ ,,	24½ ,,	2		2	1	2			= 7
											44

TABLE 1 A.

Pupal Colours.	Food.	Length of Stages I. and II.	Numbers from which averages taken.	Length of Stage III.	Numbers from which averages taken.	Length of whole period before pupation.	Numbers from which averages taken.
(1)	Absent	18 hours 10 minutes.	1	14 hours 20 minutes.	1	32 hours 30 minutes.	1
	Present	9 ,, 22½ ,,	2	14 ,, 47½ ,,	2	24 ,, 10 ,,	2
(2)	Absent						
	Present						
Dark (3)	Absent	19 ,, 20 ,,	2	15 ,, 25 ,,	4	34 ,, 30 ,,	2
	Present			14 ,, 20 ,,	1	27 ,, 15 ,,	2
(3)	Absent			14 ,, 57 ,,	5	32 ,, 30 ,,	2
	Present	9 ,, 0 ,,	1	14 ,, 10 ,,	1	23 ,, 10 ,,	1
Light (3)	Absent	18 ,, 10 ,,	1	14 ,, 37½ ,,	4	28 ,, 10 ,,	1
	Present	6 ,, 10 ,,	1	14 ,, 55 ,,	2	21 ,, 40 ,,	1
(4)	Absent			14 ,, 57½ ,,	4	32 ,, 30 ,,	1
	Present	7 ,, 6⅔ ,,	3	15 ,, 0 ,,	4	22 ,, 20 ,,	3
(5)	Absent	14 ,, 20 ,,	1	14 ,, 12½ ,,	4	24 ,, 25 ,,	2
	Present	4 ,, 50 ,,	2	14 ,, 50 ,,	2	19 ,, 40 ,,	2

to be amply supported by the last table. In order to test this conclusion more fully, I have constructed another table, in which the lengths of the periods and stages are shown in the pupæ of the various degrees of colour, without taking into account the conditions to which they had been subjected, except as regards the presence or absence of food.

(*See Table* 1 *a*, *page* 370.)

This table shows a remarkable uniformity in the length of Stage III. in pupæ of all degrees of colour, just as the preceding table showed it in all conditions of illumination, &c. On the other hand, Stages I. and II., upon the whole, exhibit a marked tendency to become longer as the pupæ become darker. There are exceptions, but the general tendency is clear, and especially so in the case of larvæ with food. Besides, the history of the exceptions lends no support to the theory that the protraction is determined by darkness, apart from any influence on the pupal colours. The table suffers from the small numbers employed in taking the averages. The careful study of these observations, made in 1887, convinces me that I was mistaken in maintaining, as the result of a far more superficial examination of the figures, that "there did not appear to be any evidence for the supposition that the gilded pupæ pass through a shorter preparatory period than those which are less brilliant, when both are equally exposed to light" (Note added Sept. 10th, 1887, to p. 339 of Phil. Trans., 1887, B.).

I believe, on the other hand, that we are warranted in the conclusion *that dark surroundings tend to prolong Stages I. and II. (taken together) of the preparatory period, and that this protraction is associated with the production of the colourless precursor of the dark superficial pigment.*

I have hitherto treated Stages I. and II. together, but, if the above conclusion be valid, it is clear that Stage II. is alone concerned; for in the earlier wandering stage the larva has not yet reached the surface by which it is to be affected, and, as soon as it reaches it, Stage II. begins.

The question as to whether darkness acts, except by promoting the formation of dark pupæ, was most easily answered by observing whether dark surfaces in strong light produce the same effect. This test was applied in the same year as follows : —

Experiments 2 and 2a.

A company of 29 mature larvæ (probably the last remaining ones) was found 1 p.m., July 30. By 3.30 it became evident that the shock had caused 16 of them to cease feeding, and enter Stage I. These were placed in two receptacles, a box lined with gilt, and a cylinder lined with black paper, with the open end closed by a sheet of clear glass, and turned to a strong east light. Others were subsequently added as they entered Stage I.

Dates.	Experiment 2. XXXI. or XLVI. Gilt (Dutch-leaf) Surroundings in strong east light.	Experiment 2a. I., II., or III. Black Surroundings in strong east light.
July 30. 3.30 p.m.	8 larvæ introduced.	8 larvæ introduced.
7.30 p.m.	3 larvæ introduced.	3 larvæ introduced.
10. 0 p.m.	3 larvæ introduced.	4 larvæ introduced.
July 31, 10. 0 a.m.	5 suspended.	4 suspended.
2.25 p.m.	13 suspended.	10 suspended.
4.50 p.m.	All 14 suspended.	All 15 suspended.
9.30 p.m.	3 pupated (1 some hours, 2 recently).	1 pupated.
10.10 p.m.	1 pupated.	3 pupated.
10.54 p.m.	1 pupated.	
12.10 midnight.	1 pupated.	
Aug. 1, 10.30 a.m.	All pupated a long time.	All pupated except 1, but 3 evidently quite recently.

No notes were taken as to the colours of the pupæ, but it may be safely assumed that those in black were far darker than the others ; and it is also clear that, although the larvæ were treated in exactly the same way (except as regards their surroundings), those in black pupated rather later than the others. Although all were suspended by 4.50 p.m. on July 31 in both sets, all but one had been suspended more than 2 hours earlier in the gilt, a time at which only two-thirds of those in the black had entered Stage III. These are less satisfactory than Experiments 1 and 1a, in the fact that probably all the larvæ were disturbed by capture, but they undoubtedly support the conclusions previously arrived at.

Experiments 3 and 3 a.

Another small batch, also found July 30, continued feeding for a day or two, and were then subjected to similar conditions. They were in fact probably placed in the same receptacles with the same conditions of illumination, but I have no note upon the latter point.

Dates.	Experiment 3. Gilt Surroundings.	Experiment 3 a. Black Surroundings.
Aug. 1, 10.45 a.m.	12 larvæ introduced.	11 larvæ introduced.
,, 12.40 p.m.	1 larva introduced.	3 larvæ introduced.
Aug. 2, 11.40 a.m.	12 pupated.	5 pupated, 6 suspended.
,, 3 p.m.	Unchanged.	7 pupated (rather recently).
	Last 1 unnoted.	Last 2 unnoted.

These brief notes show the same prolongation of the preparatory period in dark surroundings even more clearly than in Experiment 2 and 2 a. We may conclude that dark surroundings in light produce the same effect in this respect as darkness.

Other conclusions as to the effect upon pupal colours of different metallic surfaces, and of darkness as opposed to black surroundings in light, are to be gained from Experiment 1; but they are better deferred until after the examination of the experiments made in 1888.

1888.

The object of the numerous experiments made during this year was to obtain abundant confirmation of the influence of surroundings upon the pupal colours, and also to test the effect of various metallic surfaces, &c. It will be most convenient first to tabulate the whole of the experiments, briefly indicating the results of each, and then to analyse the tables in such a manner as to show the chief conclusions.

Dates of Capture and Exa-nation of Colonies.	Number and brief description of receptacles. (Roman numerals refer to detailed description at end of paper, see G. Appendix).	Position of the pupæ.	Degrees of pupal colours. (1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	Further remarks on the pupal colours, &c.	Results.
A. Three or four mixed colonies found at Malvern June 29, and Worcester June 25. Compared July 12, 13, and 16.	VII. (see description of receptacles at end of paper). Black compartment of wooden box in strong light. Experiment 4.	Crowded on roof. ..	4	14	16	6	3	2		The 16 dark (3)s were very dark for this degree. The 2 (4)s were nearly light (3)s. Very little gold throughout, except in (4)s and the 1 light (3), and these with little, considering the degrees to which they belonged.	Effects of black well shown.
		On food-plant and floor	4	5	2	3	1	1			
	III. Black cylinder, probably in darkness. Experiment 5.	On black paper roof, not very crowded.	2	1	6	1		1		All very black, somewhat relieved by light pink. The (4) almost a light (3).	
		On black paper floor. ..					1				
	6. VIII. All black cylinders in darkness.	On black paper roof ..	4	2	3	1	2			Dark (3)s with very black pigment, somewhat neutralised by a very distinct pink tint.	
		On floor.			1						
	7. ,, IX.	All on black paper roof.	3	4	2	2				Only the (3)s were at all glittering.	
	8. ,, X.	On black paper roof. ..	1		2						
		On black paper floor (may have passed Stage II., or part of it, before introduced).				1			1		
	9. ,, XI.	On black paper roof and domed glass top.		2	5	4	2			Somewhat dullish pupæ.	
	10. ,, XII.	On domed glass top.	1	2	8	1					
	11. ,, XIII.	On black paper roof and domed glass top.	1		2	2		1			

A. Three or four mixed colonies found at Malvern June 29, and Worcester June 25. Compared July 12, 13, and 16.

XV. Black wooden box in darkness. Experiment 12.	On black paper roof ..	10	13	7	5	3	1		Pigment very black in all.	Effects of black well shown.
	On floor		1	1						
XVI. Gold-lined and roofed cylinder in total darkness.* Embossed Dutch metal. Experiment 13.	All on roof, not crowded	2		3	1		1		2 dark (3)s very dark and nearly (2)s; (4) rather golden.	Practically the same results as black surfaces in darkness.
XXXI. Gilt compartment of wooden box in strong light. Polished Dutch metal. Experiment 14.	Group crowded on roof				2	4	3	5	(4)s and (5)s and light (3) on floor, golden all over, but not very brilliant for their degrees.	Characteristic effects of gilt surfaces. A curious exception in 17 was doubtless due to crowding. Those in 16 (the (1) and (2)) are less noteworthy, not being on the gilt surface.
	Isolated on roof ..							1		
	On food-plant						1			
	On floor					1				
XXXII. Compartment arranged like 14. Embossed Dutch metal. Experiment 15.	Crowded in one recess of roof					6			Most pupæ dully golden over much of dorsal area.	
	Not crowded on roof and upper shelves					4	2	5	Light (3)s as above; others not specially bright, except 1 (4) and 1 (5).	
	On lower shelves (5 pupæ crowded)					2	3	3	(5)s very bright.	
	Food-plant and floor ..				1	3	7	4	(5)s very bright.	
XXXIII. Similar to 15. Polished Dutch metal. Experiment 16.	Not crowded on roof and all shelves..			2	5	3	3	1	Dullish except the (5).	
	Food-plant and floor ..	1	1	6	5	6	2		About normal, except the (4)s, which are dull.	
XXX. Gilt wooden box in strong light. Polished Dutch metal. Experiment 17.	Crowded in corner of roof				1	4	1		Put in late, and probably already advanced in Stage II.	
	Crowded in another corner of roof	1			4	1	1			
	On side below gold ..					1				

* The larvæ were shut up in a black box, which was placed under the cylinder, the latter being covered with rugs and mats. The box was then opened by strings without interfering with the darkness, so that the larvæ cannot have seen the gilt surface at any time.

XVII. Gilt cylinder. Placed on side with clear glass front, in strong light. Polished Dutch metal. Experiment 18.	Towards back of roof, and so near the gilt back as well						1	4	A dullish lot of pupæ in most cases, considering the degrees.	Characteristic effects of gilt surfaces. A curious exception in 17 was doubtless due to crowding. Those in 16 (the (1) and (2)) are less noteworthy, not being on the gilt surface.
	Not crowded on rest of roof				3	6	8	1		
	On floor					1				
XLVI. Silver paper lined compartment of wooden box in strong light. Experiment 19.	Isolated on back ..					2			Shaded by food-plant (especially the 3 light (3s).	Influence of silver not so strong as gilt, in the direction of brilliant pupæ: light (3)s greatly preponderate.
	Crowded on back ..					3				
	Not crowded on roof ..				1	5	1		Light (3)s dull, (4) golden.	
	Crowded on roof (but in position of strong illumination)					3	2	2	Light (3)s dull, (5)s brilliant, 1 (4) very white, and yet with golden spots.	
	On floor or on food-plant					1	1		Both golden.	
XLVII. Silver paper lined cylinder with domed roof, white paper floor. In light. Experiment 20.	Crowded on roof (apex of silver dome)			5	10	8		1	All dull.	
	Somewhat isolated on roof						1		Light, but not golden.	
	On white paper floor ..						1		Golden.	
LXXVII. Wooden box with green glass windows, dull green paper lining. Experiment 21.	All on roof		5	7	6	2		1	Dullish, especially the (5).	The tendency was towards darkish forms.
White muslin bag containing food-plant, fæces, &c. Experiment 22.	On white muslin ..			4	4	11	3	1	All bright for their degrees, except (4)s and (5). These were the first larvæ to pupate, before the stock had been removed to 23.	Tendency towards lightish forms.
	On food-plant			1	1	1	1			
Plain wooden box with clear glass top, in which stock of larvæ were kept. Experiment 23.	Crowded on glass top ..	1	4	21	10	3	4	3	(4)s and (5)s bright, light (3)s fairly so, rest dull. The 4 lightest of the (5)s kept to see whether they were healthy: all emerged normally, July 24.	A very mixed result, as might be expected from the character of the environment.
	Not crowded on glass top			5	3	3	2		As above.	
	On food-plant at various levels and amounts of shade	2	3	12	11	5		3	2 (5)s very bright. Some of the other pupæ, except (1)s and (2)s, brightish.	
	On floor under piles of food and fæces	1	1	1	1	1	1		All except (1) and (2) fairly bright.	

A. Three or four mixed colonies found at Malvern June 29, and Worcester June 25. Compared July 12, 13, and 16.

B. A colony found at Oxford June 30: the larvæ were mostly mature. Pupæ compared July 12 and 20.

I. Black surroundings in strong light. Experiment 24.	Large group on roof ..	4	11	24	4			All dull.	
	On floor (deformed) ..	1							
II. Black surroundings in darkness. Experiment 25.	All crowded on roof ..	4	3	13	8			Not at all dull. Very difficult to classify with others, because the (3)s and the 9 lightest dark (3)s, and some of the darker pupæ, had a brilliancy and a development of light pink about the anterior dorsal region quite unlike the others (except in V.); and yet the dark pigment was blacker, and so compensated.	Very similar results from darkness and black surroundings in strong light.
XXXI. Gold surroundings in strong light. Compartment of wooden box. Polished Dutch metal. Experiment 26.	On roof, not crowded ..		1			2	2	The light (3)s and (4)s were bright. The others pupated very soon, and had probably been influenced before.	The more powerful effects of gold are very clear. The effect of crowding very obvious in 27. This colony seems to exhibit a strong tendency towards the production of dark varieties, and the pupæ are not easily made golden. Only 2 (4)s obtained from the whole.
	On floor			2	1				
XLVIII. Silver surroundings in light. Cylinder placed on open end, so the crumpled tin paper covering the other end formed the roof. Tin paper. Experiment 27.	Very large crowded group on roof	1	4	20	4			All very dull looking; very little gold.	
	Outlying members of same			2	1				
	Isolated on roof.. ..					2			
	Small group on roof ..			2		2			
	Small scattered group on roof			2	1	1			

C. Small company (or part of one) found July 5 at Northampton. Compared July 20.

VII. Black lined compartment in strong light. Experiment 28.	All on roof, not very crowded		1	11	1			All very dull.	This colony does not tend towards the black varieties.

C. Small company (or part of one) found July 5 at Northampton. Compared July 20.	XXXII. Gold lined compartment of same box in strong light. Embossed Dutch metal. Experiment 29.	Crowded in one coffer of roof			1	4	3		Light (3)s normal, others dull.	Effects of crowding are seen in 29. This colony does not tend towards the black varieties.
		Isolated on roof.. ..					1	2	Normally brilliant.	
	XXXIII. Gold lined compartment like XXXII. Polished Dutch metal. Experiment 30.	On roof; 2 or 3 in some of the coffers				3	5	1	The (4) not bright.	
		On floor					1		Normally bright, like the light (3)s above.	
D. Company found at Northampton July 5. Compared July 20.	Black lined cylinders in darkness; black paper floors. Expt. 31. II.	All on roof	2	7	25	1			Dark (3)s mostly very black, but with small spots of gold on some.	Characteristic results.
	„ 32. III.	All on roof	1	5	11	1			All dull, except for small spots of gold. Dark (3s) as above in II.	
	XVII. Gold lined cylinder, placed on its side. Polished Dutch metal. Experiment 33.	Not very crowded on roof				6	6	6	(4)s not brilliant, but nearly normal.	Gold as before produces more effect than silver or tin.
		On gilt back				1				
	XLVIII. Silver lined cylinder, placed on its side. Tin paper. Experiment 34.	Crowded group on high part of roof			3	9	2	1	The (4) bright and normal; the rest dullish.	Silver and tin produce almost the same effects.
		Isolated on silver paper sides				2				
	XLVII. Silver lined cylinder with domed roof; white paper floor. Silver paper. Experiment 35.	All on roof, somewhat crowded				10	4	1		
E. Small company found at Oxford July 9. Compared July 20 & 21.	XIII. Black covered cylinder in darkness; black paper floor. Experiment 36.	Near top of cylinder ..		1	6	2	3	1	A dull lot, including the (4).	Not a great effect, as compared with other experiments (24, 25, 31, 32).
		On floor				1				

E. Small company found at Oxford July 9. Compared July 20 and 31.	XXVI. Transferred July 20 in Stage III. (suspended) from XIII. to small gold lined cylinder in strong light. Polished Dutch metal. Expt. 37.	On gilt paper floor ..				2					No effect produced by transference: the pupal colours previously determined.
	XXIX. Tin box lined with gold paper, in strong light. Embossed Dutch metal. Experiment 38.	Crowded on roof ..				1	5		1		Characteristic.
		On top of glass front, near gold, and 2 on the latter, near glass			1		1	2		The (4) brilliant.	
		On floor					1				
	White muslin, probably in strong light. Experiment 39.	Muslin top of cylinder in which stock of larvæ had been kept			3						
F. Small company found at Oxford July 9. Compared July 20 and 31.	Black lined cylinders in darkness, black paper floors. Experiment 40. I.	On roof, except 1 on side and 1 on floor		5	11					All dark (3)s, except 3 very black, and nearly (2)s.	As in 36.
	,, 41. VIII.	On top of side or roof ..			10	1				As above, except 2.	
	,, 42. X.	All on roof		4	1						
	XVI. Gold lined cylinder in strong light; placed on side. Embossed Dutch metal. Experiment 43.	All on roof, not very crowded.			1	9	7			A dullish lot.	Small effect of gold.
	White muslin, probably in dim light. Experiment 44.	Muslin top of box in which stock of larvæ was kept				2	1				
G. Small company found at Oxford July 9. Compared July 20.	XLVI. Silver lined compartment in strong light. Silver paper. Experiment 45.	Not crowded on roof ..				1	5	1		The (4) silvery and light; others normal.	Characteristic.

H. Company found at Oxford July 16. Compared July 30.

VIII. Black covered cylinder in darkness. Without rugs, mats, &c. Experiment 46.	On roof or sides near it	1	1	6	4	1			All dull; the light (3) very dull.	Much like 36. The comparison of these two experiments shows that the rugs, &c., are not necessary, 46 being the darker lot.
	On floor					1				
XII. Black covered cylinder in darkness. Covered with rugs, mats, &c. Experiment 47.	On sides and paper roof			9	4				Most of the dark (3)s very black and near (2)s.	
XVI. Gold lined cylinder on side in strong light. Embossed Dutch metal. Experiment 48.	On roof, not very crowded				2	2	3	3	2 (5)s very brilliant. 2 (4)s ,, ,, 1 (4) pale and silvery.	Characteristic.
XXIX. Gold lined tin box in strong light. Embossed Dutch metal. Experiment 49.	Crowded on gilt paper ..			3	3		1	1	(5) very bright, (4) dull, dark (3)s rather dark.	
	Isolated on gilt paper ..					1	1	2	The (4) and 1 (5) dull.	
XXXI. Gold lined compartment of box, in strong light. Polished Dutch metal. Experiment 50.	On roof, rather near together						1	1	The (4) not golden, but *very* light and rather silvery.	
	On floor					1				
XLVI. Silver lined compartment of box, in strong light. Silver paper. Experiment 51.	Scattered over roof ..				2	2	2	2	(5)s normally golden, (4)s not golden, but very light and silvery.	Strong effect for silver.
XLVIII. Silver lined cylinder, placed on side. Tin paper. Experiment 52.	Crowded on roof ..			1	4	4			Light (3)s normal, rest dull.	Characteristic.
	On floor (clear glass, near silver back)						1		Dull for this degree.	

H. Company found at Oxford July 16. Compared July 30.

XLVII. Silver lined cylinder with domed roof. Silver paper. Experiment 53.	Small group on roof ..				2	1	2			Less effect than 51, due to less illumination and more crowding.
	Outlying member of group						1			
	Isolated on roof						1			
	On floor					1				
Rectangular clear glass case with perforated zinc roof, in which stock of larvæ were kept. Experiment 54.	Fixed to zinc roof ..	1	2	11	9	2			The (3)s and most dark (3)s very much alike.	Clear difference between effects of zinc and those of food-plant.
	On clear glass sides ..				2					
	On food-plant at various depths			1	3	1	1		All but the dark (3) golden for their degrees.	
Transferred, in Stage II. or III., from zinc roof of case, in which stock was kept, to small gold lined cylinder XXVI. in strong light. Polished Dutch metal. Experiment 55.	Not crowded on gilt sides and roof				1		2		The (4)s dull, although somewhat golden.	Here transference has produced a distinct effect on some of the pupæ. Compare 54.
	On gilt floor (evidently 2 larvæ which had been suspended, Stage III.).				1	1				

I. Company found at Oxford July 16. Compared July 31.

This company compares with B in an interesting manner, the whole tendency being the exact opposite. Bright forms are produced easily, and the darkest not at all.

Black lined or covered cylinders in darkness. All but II. covered with rugs, &c. But darkness almost complete without this. Experiment 56. XI.	On top of sides			2	1	1				Small effects.
,, 57. XIV.	On sides and black paper top			4	1	1			The dark (3)s very black.	
,, 58. II.	On roof		1	19	3	1				
	On floor			1	1					
,, 59. III.	All on roof		1	9	4	4	1			
XXVII. Gold lined cylinder in strong light. Embossed Dutch metal. Experiment 60.	On roof, not crowded ..							3	Very brilliant.	Very strong effects.
XVII. Gold lined cylinder in strong light (placed on its open end). Polished Dutch metal. Experiment 61.	Not very crowded group on roof					1	1	2	The (4) dull; both (5)s very brilliant, but one silvery rather than golden.	
	Not crowded group on roof					2	2	1	(5) very brilliant; (4)s not very golden, but very light.	
	Isolated on roof							1	Very light, but not very glittering.	
	Glass, side below gilt ..					1				

I. Company found at Oxford July 16. Compared July 31.

XXX. Gold lined box in strong light. Polished Dutch metal. Experiment 62.	Large group in one corner of roof		1	3	10	3	3	2		Influence of crowding well seen when this is compared with 60 and 61.
	In small separate groups on roof			1		6		2	1 (5) very brilliant.	
	On floor among food and fæces				1		1		Both dull.	
Food-plant in the field. Found as pupæ [3], or larvæ in Stage III. [3], or some earlier stage [6]. Experiment 63.	3 pupæ and 3 larvæ suspended to food-plant in the field, July 16							3	Brilliant. The 3 larvæ died.	This proves that healthy pupæ of the greatest brilliancy may occur in nature on the food-plant, although they are generally diseased.
	Larvæ pupating soon after capture, having passed some of their stages on the food-plant in the field..					1	2	3	(5)s brilliant, the (4)s unusually golden. The imagos emerged normally from all these.	
Rectangular glass box with perforated zinc top, in which stock of larvæ was kept. Angles bound with black, and a shallow box (black outside) placed in bottom. Experiment 64.	On zinc roof			7	2	1			A dipterous larva emerged from 1 of the (3)s.	As in 54.
	On glass sides (1 low down near angle bound with black, and a black wooden box for food) ..				2				The 1 low down, black, but relieved by gold.	
	On food-plant at various depths			1	1		1	1	(4) and (5) dull; dark (3) very dark.	
Transferred from stock (zinc roof in Stage III.), to embossed Dutch metal lined cylinder XXVII., in strong light. Experiment 65.	On floor				1	1	1			
	Pupated on white and blue plate					1	1		The (4) somewhat dull.	Some effect produced. Probably transferred at beginning of Stage III.

This company compares with B in an interesting manner, the whole tendency being the exact opposite. Bright forms are produced easily, and the darkest not at all.

I. Company found at Oxford July 16. Compared July 31.

Transferred in Stage II. from stock in rectangular glass case (probably on roof) to some of the gilt and silvered compartments (XXXIV. to XLV.) of wooden box: 1 larva in each compartment. Experiment 66.	On roof of polished Dutch metal lined compartments					2				Greatest effect when transferred for the longest time — the (4).
	On floor of polished Dutch metal lined compartment ..					1				
	On roof of embossed and polished Dutch metal lined compartment				1					
	On roof of tin paper lined compartments			1	2					
	On roof of tin paper lined compartment; pupated later than others						1			
	On roof of silver paper lined compartment (XLI.).				1					
2 larvæ transferred in Stage III. from III. (darkness) to strong light in XXXIX. (Polished and embossed Dutch metal), and XLV. (tin paper). Experiment 67.	On gilt floor			1						No effect. Interesting to compare with 66, in which transference took place earlier.
	On silver floor			1						
Transferred in Stage III. from stock to white paper. Experiment 68.	On food-plant in Stage III. to white paper ..					1				
	On zinc roof in Stage III. to white paper			1	1	1	1		The (4) dull.	Very little effect.

This company compares with B in an interesting manner, the whole tendency being the exact opposite. Bright forms are produced easily, and the darkest not at all.

		Pupal Colours.							
		(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	
BLACK SURROUNDINGS IN DARKNESS. Pupæ found on floor included, except in Experiment 8 (see special note in description of experiment).	Experiment (1887) 1	1	1	4	2	4	1	1	=14
	,, (1887) 1 A	2		2	1	2			= 7
	,, 6	4	2	4	1	2			=13
	,, 7	3	4	2	2				=11
	,, 8	1		2					= 3
	,, 9		2	5	4	2			=13
	,, 10	1	2	8	1				=12
	,, 11	1		2	2		1		= 6
	,, 12	10	14	8	5	3	1		=41
	,, 25	4	3	13	8				=28
	,, 31	2	7	25	1				=35
	,, 32	1	5	11	1				=18
	,, 36		1	6	3	3	1		=14
	,, 40		5	11					=16
	,, 41			10	1				=11
	,, 42		4	1					= 5
	,, 46	1	1	6	4	2			=14
	,, 47			9	4				=13
	,, 56			2	1	1			= 4
	,, 57			4	1	1			= 6
	,, 58		1	20	4	1			=26
	,, 59		1	9	4	4	1		=19
	Totals..	31	53	164	50	25	5	1	329
	Results expressed as percentages of the total	9·4	16·1	50·0	15·2	7·6	1·5	·3	
BLACK SURROUNDINGS IN STRONG LIGHT. Pupæ found on floor included, except in Experiment 4 (where they were not distinguished from those on food-plant).	Experiment 4	4	14	16	6	3	2		=45
	,, 24	5	11	24	4				=44
	,, 28		1	11	1				=13
	Totals..	9	26	51	11	3	2		102
	Results expressed as percentages of the total	8·8	25·5	50·0	10·8	2·9	2·0		
PERFORATED ZINC ROOF IN LIGHT.	Experiment 54	1	2	11	9	2			=25
	,, 64			7	2	1			=10
	Totals..	1	2	18	11	3			35
	Results expressed as percentages of the total	2·9	5·7	51·4	31·4	8·6			

The influence of Dark Surroundings in light as contrasted with the effects of darkness.

In my previous paper (*l. c.*, pp. 364, 365) I had made a pair of experiments in order to test the relative efficiency of black surroundings in light and in darkness. The results favoured the latter, which, upon the whole, produced somewhat darker pupæ, although they also included some which were lighter than the others. The numbers were insufficient for any safe conclusion, and I was therefore anxious to repeat the experiments on a much larger scale, especially considering that *larvæ* brought up in darkness are as a rule much less dark than those brought up among dark surroundings in strong light (see the earlier part of this paper). Hence a far larger number of experiments were devoted to the solution of this question than of any other. The table at p. 384 shows the results of all such experiments upon this species in 1887 and 1888, omitting No. 5, the arrangement of which is uncertain, and including the pupæ formed upon a darkish surface of perforated zinc.

Below, the percentages are placed one under the other, and compared with the results obtained in 1886, and with the single experiment in which a gilt surface (embossed Dutch metal, Experiment 13) was used in complete darkness.

Degrees of Colour.	(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	Numbers of Pupæ.
α. Black surroundings in darkness, 1886	15·4	15·4	30·8	23·0	15·4			13
β. Black surroundings in darkness, 1887 & 1888	9·4	16·1	50·0	15·2	7·6	1·6	·3	329
γ. Gilt surroundings, in darkness, 1888	28·6		42·9	14·3		14·3		7
δ. Black surroundings in strong light, 1886 ..	9·8	29·3	25·0	20·7	13·0	2·2		92
ϵ. Black surroundings in strong light, 1888 ..	8·8	25·5	50·0	10·8	2·9	2·0		102
ζ. Zinc surroundings in strong light, 1888 ..	2·9	5·7	51·4	31·4	8·6			35

This table indicates that there is very little difference between the pupæ of α, β, as compared with δ, ϵ. α is not much to be relied on, because of the small numbers employed. As regards the darkest pupæ, β, δ, and ϵ are practically equal, but there is a much smaller proportion of (2)s in β. In other respects no great difference can be made out, for the percentages of β are either practically the same as either δ or ϵ, or intermediate between them. The wide difference between the (2)s in the averages of these large numbers justifies the conclusion that darkness tends rather less towards the appearance of dark pupæ, than dark surroundings in strong light.

So far as it is possible to judge from the small numbers, gilt surfaces in complete darkness (γ) produce, as we should expect, the same effect as black surfaces subjected to the same condition.

The larger numbers attached to a darkish surface of zinc (ζ) tend in the same direction as those exposed to black surfaces, but are, as might be anticipated, stronger in the intermediate forms, and weaker in the darkest.

The influence of various bright metallic surfaces.

The following is a summary of all experiments of this kind in 1887 and 1888. In those of the latter year the crowded are carefully separated from the uncrowded pupæ, and those which pupated on the food-plant or floor are excluded.

(*See Table, pages* 387, 388.)

The percentages are now placed under one another to facilitate comparison, the results obtained by "gilt" paper in 1886 being also added.

Degrees of Colour.	(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	Numbers of Pupæ.
α. Embossed Dutch metal, not crowded ..			2·9	5·7	25·7	28·6	37·1	35
β. Embossed Dutch metal, crowded			10·9	36·9	45·7	2·2	4·3	46
γ. Dutch leaf, 1886		1·5	3·0	10·4	23·9	40·3	20·9	67
δ. Dutch leaf, 1887				30·0	10·0	10·0	50·0	10
ϵ. Polished Dutch metal, not crowded ..		1·2	2·4	21·4	31·0	29·7	14·3	84
ζ. Polished Dutch metal, crowded	1·7	1·7	6·9	29·3	31·0	13·8	15·5	58
η. Silver paper (compartment), not crowded				16·6	58·3	16·6	8·3	24
θ. Silver paper (compartment), crowded ..					60·0	20·0	20·0	10
ι. Silver-paper (cylinder), not crowded ..						100		3
κ. Silver-paper (cylinder), crowded			11·4	50·0	29·5	6·8	2·3	44
λ. Tin-plate, 1887			8·3	16·7	8·3	58·3	8·3	12
μ. Tin-paper, not crowded			36·4	36·4	27·3			11
ν. Tin-paper, crowded	1·7	7·0	15·6	29·8	14·0	1·7		57

"Gilt" paper (covered with different forms of "Dutch metal,"—a variety of brass).

		Experiments.	Pupal Colours. (1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	Totals
Bright Dutch metal with an embossed pattern on it.	Pupæ not crowded.	Experiment 15 ..					4	2	5	=11
		,, 29 ..					1	2		= 3
		,, 38 ..			1		1	2		= 4
		,, 48 ..				2	2	3	3	=10
		,, 49 ..					1	1	2	= 4
		,, 60 ..							3	= 3
		Totals..			1	2	9	10	13	35
		Results expressed as percentages of the total			2·9	5·7	25·7	28·6	37·1	
	Pupæ crowded.	Experiment 15 ..					6			= 6
		,, 29 ..			1	4	3			= 8
		,, 38 ..				1	5		1	= 7
		,, 43 ..			1	9	7			=17
		,, 49 ..			3	3		1	1	= 8
		Totals..			5	17	21	1	2	46
		Results expressed as percentages of the total			10·9	36·9	45·7	2·2	4·3	
1887. Bright, but not highly polished Dutch metal applied to the paper in the form of "leaf."	No distinction made.	Experiment 1 ..				3	1	1	4	= 9
		,, 1A ..							1	= 1
		Totals..				3	1	1	5	10
		Results expressed as percentages of the total				30·0	10·0	10·0	50·0	
Bright Dutch metal with a highly polished surface.	Pupæ not crowded.	Experiment 14 ..							1	= 1
		,, 16 ..			2	5	3	3	1	=14
		,, 17 ..					1			= 1
		,, 18 ..				3	6	9	5	=23
		,, 26 ..		1			2	2		= 5
		,, 30 ..				3	5	1		= 9
		,, 33 ..				7	6	6		=19
		,, 50 ..						1	1	= 2
		,, 61 ..					3	3	4	=10
		Totals..		1	2	18	26	25	12	84
		Results expressed as percentages of the total		1·2	2·4	21·4	31·0	29·7	14·3	
	Pupæ crowded.	Experiment 14 ..				2	4	3	5	=14
		,, 17 ..	1			5	5	2		=13
		,, 62 ..		1	4	10	9	3	4	=31
		Totals..	1	1	4	17	18	8	9	58
		Results expressed as percentages of the total	1·7	1·7	6·9	29·3	31·0	13·8	15·5	

Bright surface of metallic silver.	Silver paper, bright, but not highly polished, in strong light (compartment of wooden box).	Pupæ not crowded.	Experiment 19 ..				1	7	1		= 9
			,, 45 ..				1	5	1		= 7
			,, 51 ..				2	2	2	2	= 8
			Totals..				4	14	4	2	24
			Results expressed as percentages of the total				16·6	58·3	16·6	8·3	
		Pupæ crowded.	Experiment 19 ..					6	2	2	=10
			Results expressed as percentages of the total					60·0	20·0	20·0	
	Similar silver paper in less strong light (domed roof of cylinder).	Pupæ not crowded.	Experiment 20 ..						1		= 1
			,, 53 ..						2		= 2
			Totals..						3		3
			Results expressed as percentages of the total						100·		
		Pupæ crowded.	Experiment 20 ..			5	10	8		1	=24
			,, 35 ..				10	4	1		=15
			,, 53 ..				2	1	2		= 5
			Totals..			5	22	13	3	1	44
			Results expressed as percentages of the total			11·4	50·0	29·5	6·8	2·3	
Bright surface of metallic tin.	1887. Bright and highly polished tin-plate.	No distinction made.	Experiment 1 ..				2	1	3		= 6
			,, 1 A ..			1			4	1	= 6
			Totals..			1	2	1	7	1	12
			Results expressed as percentages of the total			8·3	16·7	8·3	58·3	8·3	
	Bright and polished surface of tin-paper (an artificial "silver paper"), greyer and less bright than tin-plate.	Pupæ not crowded.	Experiment 27 ..			4	2	3			= 9
			,, 34 ..				2				= 2
			Totals..			4	4	3			11
			Results expressed as percentages of the total			36·4	36·4	27·3			
		Pupæ crowded.	Experiment 27 ..	1	4	22	4	2			=33
			,, 34 ..			3	9	2	1		=15
			,, 52 ..			1	4	4			= 9
			Totals..	1	4	26	17	8	1		57
			Results expressed as percentages of the total	1·7	7·0	45·6	29·8	14·0	1·7		

The percentages of δ, θ, ι, λ, and μ depend on such small totals that they are not of much value. The remaining figures are mostly trustworthy, and lead to some interesting conclusions.

The comparison of α with β, and of ϵ with ζ, entirely confirm the conclusion at which I arrived in 1886,—that crowding the larvæ tends to produce dark pupæ, the effect being presumably due to the influence upon each larva of the dark skins of its neighbours.

Any supposed chemical influence of the surface is entirely dispelled by the comparison. When the same material is employed in different forms, different effects may be produced if the character of the reflected light is altered thereby. Thus Dutch metal produces least effect when it possesses a very highly polished surface (ϵ and ζ), most when it is broken up by a small raised pattern, as in α (β shows the effects of crowding to a remarkable extent), while the Dutch leaf, which is not highly polished, but of a very bright golden appearance, also produces powerful effects (γ). It is probable, indeed, that this latter is the most powerful form of the substance, for the averages of 1886 are brought down by the inclusion of pupæ which were excluded or separated in 1888 (pupæ on the floors or food-plant of cases, and crowded pupæ).

So, too, the silver paper produced far more effect when in strong light (η, θ) than when the light was somewhat dim (ι, κ), and bright tin-plate (λ), although the numbers were very small, is evidently far more powerful than the duller, greyer surface of tin-paper.

In 1886 I had sometimes thought that the pupæ produced on white opal glass tended to be silvery rather than golden, and one object I had in view was to test for any such susceptibility. This was the chief reason for employing the silver and tin surfaces. The results were entirely negative. Single pupæ belonging to (5)s or (4)s are occasionally met with having a silvery instead of a golden lustre, but there was no evidence that they were commoner on the surfaces with a corresponding colour. The tendency of silvery surfaces is in the same direction as that of golden ones, only it is not equally powerful.

Other Results.

The effects of a few other conditions not tested by large numbers of individuals are shown in the table below, the percentages from white surroundings in 1886 being also included for the purpose of comparison.

			(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	Numbers of Pupæ.
White surroundings (paper and opal glass), 1886 ..				4·8	14·5	25·5	30·3	17·2	7·6	145
White muslin.		Experiment 22 ..			4	4	11	3	1	= 23
		,, 39 ..			3					= 3
		,, 44 ..				2	1			= 3
		Totals..			7	6	12	3	1	29
		Results expressed as percentages of the total			24·1	20·7	41·4	10·3	3·4	
Clear glass.	Pupæ not crowded.	Experiment 23 ..			5	3	3	2		= 13
		,, 54 ..				2				= 2
		,, 64 ..				2				= 2
		Totals..			5	7	3	2		17
		Results expressed as percentages of the total			29·4	41·2	17·6	11·8		
	Pupæ crowded.	Experiment 23 ..	1	4	21	10	3	4	3	= 46
		Results expressed as percentages of the total	2·2	8·7	43·7	21·7	6·5	8·7	6·5	
Deep green glass in front of a dark green background.		Experiment 21 ..		5	7	6	2		1	= 21
		Results expressed as percentages of the total		23·8	33·3	28·6	9·5		4·8	

It is thus seen that white muslin was not nearly so powerful as the white paper and opal glass employed in 1886. The difference corresponds to the far smaller amount of light reflected from the former, and its feebler illumination under the conditions of the experiment.

Clear glass, when uncrowded, chiefly produced intermediate forms, while the crowded pupæ were considerably darker as a whole, although including 6·5 °/₀ of the lightest varieties. It will probably be found that larvæ suspended from threads at a distance from any background would tend, like the isolated ones on clear glass, to produce intermediate forms.

The effect of light transmitted through deep green glass was, with a single exception, to produce dark or intermediate pupæ. This will be alluded to further on in discussing the very different effect upon *V. io* of the same light reflected from a white background.

The few transference experiments need not be extracted from the descriptive table. They quite confirm, although they add nothing to, the results obtained with larger and more carefully conducted experiments in 1886.

The general result of the whole series of 68 experiments conducted, in 1888, upon many hundreds of pupæ is to afford abundant confirmation of the earlier work, at the same time extending it in many directions.

1892.

The only experiment upon *V. urticæ* in this year was one with conflicting colours. The results of such experiments have so important a bearing upon the physiology of the adjustment of pupal colours that I was anxious to repeat them, if possible, in a more searching manner.

In 1886 I devoted a great deal of time and attention to the subject (Phil. Trans. 1887, pp. 368—392), exposing the larvæ during Stage III. to gilt and black surroundings in compartmented tubes, and frames with perforated shelves between the contrasted colours.

The following questions as to the physiology of the process are answered by the results of these experiments:—(a) *The possible influence of colour upon the larval eyes.* Blinding the larvæ had failed to affect the power of adjustment, and this experiment would apply a valuable test to the conclusion that the eyes are of no importance in the matter. If the colour surrounding the anterior part of the larva had no more influence than that surrounding the posterior part, the conclusions from the blinding experiments receive strong confirmation. (b) *The direct photographic effect of light upon the skin.* Although the earlier view that the pupal tints are determined in this way *after* the last ecdysis, has been completely upset by the results of transference experiments, it still remained possible that the light directly influences the developing pupa beneath the larval cuticle, and thus determines the presence or absence of the colourless precursor of the pigment which subsequently appears. If two colours with opposite influences produced opposite effects on the two parts of the pupa to which they had been respectively applied, the suggestion made above would receive very strong support. If not, if some intermediate tint was common to the whole pupal surface, the above suggestion could only hold if we suppose that the superficial layer in which these changes take place is in a condition of such complete physiological unity that each local influence is just as powerful in another part of the layer where an opposite influence is at work as it is in the area directly exposed to its action. Although such a view is difficult to conceive, the tendency of recent research has certainly afforded proof of the organic continuity of tissues which such a hypothesis requires. Dr. Michael Foster tells me that he does not by any means consider this hypothesis to be essentially improbable as an explanation of the adjustment of colour. (c) *The influence of light through the nervous system.* If the nervous system receives the stimulus, and controls the result, a general effect from a local influence is to be expected. There is no difficulty whatever in the supposition that the impulses from conflicting stimuli applied to different areas of the body would become neutralized when they meet in some nervous centre or centres, and hence result in efferent impulses which produce a uniform intermediate effect. This conclusion is also supported by the power of adjusting the colours of the cocoon, which can still be maintained to exist in the genus *Halias*, and which receives its most probable explanation on the supposition that the nervous system is concerned.

In addition to its direct bearing on these important questions, the experiment also affords interesting information as to the relative strengths of stimuli opposed to each other, and (in the form in which it has been conducted in 1892) as to the possible exercise of choice by the larva.

The results obtained in 1886 are well known to be negative—a uniform result following the two opposed local influences. I was anxious to apply the experiment in such a form that the larvæ would be exposed to conflicting stimuli during the most sensitive stage (II.), as well as the last.

With this object in view, I constructed the case which is represented, about one-fifth of the true size, in Plate XV., fig. 5. It consisted of three rows of compartments, each row containing 14. The compartments were 8·1 cm. high in the two upper rows, rather higher in the lowest row. Their width varied from 1·5 to 5·0 cm.; their depth was 1·2 cm. at the bottom, while above it tapered away to a chink only 0·3 cm. wide. The front of each row was covered in by a strip of clear glass, which sloped gently backwards, resting upon the wedge-shaped divisions between the compartments. These divisions and the backs of the compartments were lined with alternating strips of gilt (polished Dutch metal) and black paper (black tissue paper). Those of the lowest row were crossed by two narrow gilt strips, 0·8 cm. broad, separated by black bands of three times the breadth, the uppermost being rather broader, and the narrow roof and floor (about 1·2 cm. wide) being gilt. The compartments of the two upper rows were crossed by strips of black and gilt, with an equal breadth of about 1·5 cm., except the uppermost (black in the top row, gilt in the middle one), which was rather broader. The narrow roof and floor were opposite in colour to the adjacent strips.

In use, the case was kept vertical in the position shown in fig. 5, and a single larva, having ceased to feed, was introduced into each compartment. Hence no allowance has to be made for crowding. The larvæ were left undisturbed in the compartments, and, after their first excitement, passed all the stages in a normal manner, and formed pupæ, suspended to either the back of the compartments or the glass front. It is clear that two or more parts of the larval body, succeeding each other antero-posteriorly, had been subjected to conflicting impulses during the whole of the sensitive period.

The last larvæ of a company found towards the end of August at Oxford, being mature, were at once placed in the case just described. The pupæ were compared August 28, with the following results:—

	Degrees of Colour of Pupæ.	(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)
Fixed to vertical back of Rows I. and II., in which the black and gold bands are of equal width, or to the glass front.	3 fixed to junction of gold and black, the body on black, head in the middle of gold			1	1	1		
	3 fixed to junction of gold and black, the body on gold, head in the middle of black				2	1		
	2 fixed just above junction of gold and black, the body on gold, head and posterior end on black			1		1		
	4 fixed on the glass just opposite this level			2		2		
	3 fixed on middle of gold, head and anterior part on black					3		
	3 fixed below middle of gold, so that body lay upon black band, and the head just overlapped the next gold band			2		1		
	4 fixed on glass just opposite this level				2	1	1	
Fixed similarly to back (except one on side), or glass of Row III., in which the gold bands are only ⅓ the width of the black ones.	5 fixed on junction of gold and black, so that the whole pupa was on black, the head not reaching the next gold band	1		2	1	1		
	1 fixed on glass opposite this level			1				
	1 fixed just below junction of gold and black, so that head just overlapped next gold band					1		
	3 fixed just above the middle of gold, so that all the rest of the pupa was on the black band			3				
	1 fixed on the junction of gold and black, so that posterior end crossed the gold, and the rest of pupa was on black			1				
	1 fixed on side of compartment, the middle of the pupa crossing a gold band, the rest on black			1				

These pupæ were wonderfully uniform and transitional, so that their classification was a matter of great difficulty. It will be noted that there are only two out of the whole number which were other than intermediate [some form of (3)] varieties. There was remarkably little gold on the pupæ, the classification of the (3)s being entirely dependent on the amount and depth of the pigments present.

In order to test the results of this experiment still further, a different mode of comparison was adopted. Neglecting the pupæ fixed to the glass, all the others in Rows I. and II. were arranged according to the parts of the body which were exposed to black or gold. They fell into four classes:—

A. — 3 pupæ with head well in gold.			
B. — 6	,,	,,	black.
C. — 3	,,	just in gold.	
D. — 2	,,	,,	black.

But there was no tendency for the anterior part of pupæ A. and C. to be any lighter than the same part of B. and D. respectively.

Those fixed on Row III. were then similarly compared. They fell into two classes:—

E. — 10 pupæ with head in black.		
F. — 1 pupa	,,	gold.

The last was certainly lighter than any of E., but it was light altogether, and not specially about the head or anterior part.

It is thus clear that the colours did not produce localized effects. The anterior or posterior end of a pupa was often specially light, but this was quite irrespective of the colour of the band against which it had rested.

These comparisons were carried out with the greatest care, the pupæ being not only arranged side by side on a sheet of white paper, with the light falling on the same side of each of them (for this plan is always adopted in my comparison of pupæ), but the sheet was gradually turned round to permit their equal illumination on all parts of the body.

Although the results are entirely negative, thus confirming my earlier experiments in 1886, it is clear that the pupæ in Row III., with the broader black bands, were distinctly darker as a whole than those in Rows I. and II. Although no localised effects are produced, the gold and the black certainly influence the pupa, and when the relative extent of one of the areas is increased, its effect, as tested by the whole pupal surface, tends to preponderate over that of the other.

The bearing of this experiment upon the important physiological questions set forth at the beginning of this section is thus clear, and although nothing new is added to my earlier work, it is at any rate important to confirm by the use of an improved method an experiment upon which conclusions of so much interest depend.

Mr. Bateson (Trans. Ent. Soc. Lond., 1892, p. 212) states that he gleaned "no hint at all of the physiology of these phenomena," as indeed was to be expected from the class of my experiments of 1886, which he had selected for repetition. But although he failed to select experiments which would have yielded some information on the point, the experiments had nevertheless been made in 1886, and published with every detail in 1887. Other workers are likely to be discouraged rather than inspired by a statement which, although no doubt true of the writer himself, does not represent the knowledge of the time at which he wrote. For we do possess certain clear indications as to the physiology of these processes, even though they may not carry us very far.

I now turn to the bearing of the recent conflicting colour experiments upon the smaller points already alluded to (see page 392).

The larvæ, as a rule, tend to mount a vertical surface, and suspend themselves from the under side of any ledge projecting from it, but in the absence of the latter they will fix themselves to the vertical surface itself. Advantage of this habit was taken in compelling the larvæ to fix themselves to the vertical back of the conflicting colour case, where the conditions of the experiment could be carried out in the best manner. Reference to fig. 5 (Plate XV.) will show the positions selected by many of the larvæ; for the white bosses of silk from which the pupæ were suspended are clearly indicated as white spots in the collotype. It is thus seen that they did not mount to the highest points, but suspended themselves about half-way up or a little above this level; and this was true of all the rows, irrespective of the band of colour which happened to be at this horizon. There is no evidence that any selection was made, although there is no doubt that the resulting pupæ would have been less conspicuous on the black than on the gold.

We are forced to conclude that the larvæ ascended the lessening space, and stopped at the point where the narrow width of the chink would have endangered the success of the process of pupation which is so precarious in this group of Lepidoptera. Such an instinct would be extremely valuable to species pupating in cracks and chinks of stone or bark, and it certainly seems to exist. The evidence of it was equally clear in *V. io*, and was found in both kinds of case employed with this species (see the level of the bosses of silk on the black part of fig. 6 in Plate XV.).

As to the relative strength of black and gilt when equal in extent, the intermediate position of the pupæ indicates a tolerably equal balance, inclining rather to the side of the latter in the number of light (3)s and the (4). When the extent of the areas becomes relatively unequal, the balance of strength is of course upset, giving black by far the greater power under the particular conditions of the experiment as carried out in the lowest row of compartments.

2. Experiments on the pupa of Vanessa io, 1888, 1891, and 1892.

In working in 1886 I had experimented upon a very few individuals of this species, and had shown that they are highly susceptible. I was most anxious to investigate the species very fully, for it appeared to be even more suitable for the purposes of this enquiry than *Vanessa urticæ*. Although the number of individuals tested has been smaller than in the latter species, the results are more decisive, and I think we may consider that our knowledge of these two *Vanessidæ* is, in this respect, about on a level.

The first necessity was the construction of a scale of pupal colours in which each marked form is represented by a number. This was made in 1888, and found to work well in subsequent years. The divisions are made, as far as possible, equivalent to those of *V. urticæ*, and, indeed, the division into 5 classes was the one into which a large series of individuals of *V. io* most naturally falls. If we substitute green for gold, and remember that the intermediate forms are not so common and do not require subdivision into 3 classes, the criteria adopted in the two arrangements become almost identical, as will be seen below.

(1) (2) The darkest forms; the underlying green is completely or very nearly [in some (2)s] concealed by the superficial pigment, which is blacker in (1), lighter in (2).

(3) Intermediate forms, with a varying amount of pigment, although never sufficient to conceal the green colour, which is prominent on the pupa.

(4) (5) Distinct green forms, very bright and glittering in (5), somewhat duller and with more pigment in (4). The small amount of pigment tends to exhibit a reddish tint.

The chief and obvious distinction is between (1) + (2) and (4) + (5). Completely transitional forms occur, especially among the (3)s, but these are not very common, and a large majority of the pupæ are classified with the greatest ease, far more so than in the case of *V. urticæ*.

A figure of the green and golden form (5) is shown in Phil. Trans., 1887, B, plate 26, fig. 7, and a representation of the cuticle of the wing of the same form in fig. 10 (magnified 7 diameters), showing the small amount of superficial pigment, some of which is reddish. In fig. 11 there is a similar representation of the pupal wing of a dark form, (1), showing the relative abundance and intensity of the cuticular pigment.

There is little doubt that the green forms of *V. io* truly represent the golden ones of *V. urticæ*, the former being also distinctly golden, although this appearance is rendered less prominent because of the green colouring. They are, furthermore, produced in almost every case by the same stimuli.

In the following account all the experiments which are intended to test the effects of various coloured backgrounds and screens will first be given, with their details. The results will be analysed at the end of the section concerned with this species, *after* the consideration of various other experiments, dealing with the length and susceptibility of the preparatory stages and the effects of conflicting colours. Thus the arrangement will not necessarily follow the order in which the experiments succeeded each other.

The effects of various colours will now be shown in the accompanying tables.

Companies of Larvæ made use of.	Receptacles employed.	Positions of pupæ.	Pupal Colours. (1)	(2)	(3)	(4)	(5)	Results.
A. Small lot of 9 found at Oxford, July 9, 1888, together with 1 larva taken previously; compared July 24. Larvæ fed for several days in the receptacles described.	IV. Black lined cylinder in strong light. Experiment 1.	4 larvæ introduced; 1 died; 3 pupæ suspended to roof, of which 1 died	2					The (5)s precisely alike, and bright green forms. Hence the green and gilt surroundings produced exactly the same effect. The results of black were very pronounced.
	XXVII. Gold lined cylinder in strong light. Embossed Dutch metal. Experiment 2.	4 introduced (all fixed to roof).					4	
	LXIX. Green tissue paper covered cylinder. Experiment 3.	1 introduced (on roof). ..					1	
	LXX. Green tissue paper covered cylinder. Experiment 4.	1 introduced (on roof). ..					1	
B. Company found at Chipping Norton towards the end of July, 1888; compared Aug. 9. It is possible that 2 or 3 larvæ from D. were accidentally introduced; and 3 from C. were intermixed with Experiment 6. It is probable that this and the next lot belong to one company, as they were of the same age, and found on the same bed of nettles.	I. Black lined cylinder in complete darkness (covered with rugs, &c.). Experiment 5.	5 on floor.	2	1	1		1	Effect of darkness was very irregular.
		4 on roof in group.	2		1	1		
		4 on roof in scattered group, the (5) outlying.	1	2			1	
		13 introduced.						
	VIII. Black lined cylinder in complete darkness (covered with rugs, &c.). Experiment 6.	3 of these larvæ were taken from C company. 6 introduced (all on roof).			2	3	1	
	XXV. Gold lined cylinder. Dutch leaf. Experiment 7.	1 introduced (on roof). ..					1	The gilt surroundings produced bright green pupæ almost uniformly.

XVI. Gold lined cylinder. Embossed Dutch metal. Experiment 8.	6 introduced; all in a somewhat scattered group on roof near background (gilt end). The (2) was in the middle of the group.	1		3	2	The gilt surroundings produced bright green pupæ almost uniformly.
XXIX. Gold lined tin box. Embossed Dutch metal. Experiment 9.	1 on floor (perhaps had been suspended). 1 dead larva on floor. 3 dead larvæ on roof. 1 pupa on roof, somewhat separated from these latter. — 6 introduced.				2	
XVII. Gold lined cylinder. Polished Dutch metal. Experiment 10.	7 in small group on roof (1 of them dead and discoloured). 1 on floor. — 8 introduced.				7	
XX. Gold lined cylinder. Polished Dutch metal. Experiment 11.	1 dead on floor. 1 deformed on floor, a (5). 4 close together on roof. — 6 introduced.		1		4	
XXVI. Gold lined cylinder. Polished Dutch metal. Experiment 12.	1 introduced (on roof). ..				1	
XXXI. Gold lined compartment. Polished Dutch metal. Experiment 13.	All on roof. 4 in group (1 (4)). 1 isolated. 2 in group (1 (4)). — 7 introduced.			2	5	

B. Company found at Chipping Norton towards the end of July, 1888; compared Aug. 9. It is possible that 2 or 3 larvæ from D. were accidentally introduced; and 3 from C. were intermixed with Experiment 6. It is probable that this and the next lot belong to one company, as they were of the same age, and found on the same bed of nettles.

XLVI. Silver paper lined compartment. Experiment 14.	5 crowded on roof. 1 dead larva. 1 dead pupa, discoloured. — 7 introduced.			1	1	3	Effects not equal to gilt.
LXIX. Green tissue paper covered cylinder. Experiment 15.	1 introduced (fixed to side near roof).					1	Effects like that of gilt.
LXXVII. White paper lined box with green glass windows. Experiment 16.	11 in a longish but crowded group on roof. 1 on floor. — 12 introduced.					12	
Found in stock of larvæ. Experiment 17.	2 pupæ low down on food-plant, and shaded; isolated.			1	1		These pupæ on leaves are usually bright green. Here they were probably affected by shade.
Black lined cylinders in complete darkness (rugs, &c.) Experiment 18. II.	Group of 10 on roof, including 1 dead larva		2	5	1	1	Irregular results, inclining on the whole towards dark pupæ.
	Small group of 2 on another part of roof. 12 introduced ..	1				1	
,, 19. X.	1 on floor (a (1)). 4 on roof. 1 larva dead. — 6 larvæ introduced.	2		1	2		
Gold lined compartments. Polished Dutch metal. Experiment 20. XXXIV.	On floor (fallen and injured). 1 larva introduced				1		Much greater effect of gold than silver in the direction of green forms.
,, 21. XXXV.	On floor. 1 larva introduced.					1	
,, 22. XXXVI.	Fixed to roof. 1 larva introduced					1	

B. Company found at Chipping Norton towards the end of July, 1888; compared Aug. 9. It is possible that 2 or 3 larvæ from D. were accidentally introduced; and 3 from C. were intermixed with Experiment 6. It is probable that this and the next lot belong to one company, as they were of the same age, and found on the same bed of nettles.

C. A company found at Chipping Norton towards the end of July, 1888; compared Aug. 9. Like the larvæ of B, they were changing their last skins when found, and were upon the same bed of nettles. It is probable that they belonged to the same company; 3 of these were intermixed with B in Expt. 6, and it is possible that larvæ of B may have been introduced into Expts. 31 and 32, although this is unlikely.

Gold lined compartments. Mixed polished and embossed Dutch metal.							
Experiment 23. XXXVII.	Fixed to roof. I larva introduced			1			Much greater effect of gold than silver in the direction of green forms.
,, 24. XXXVIII.	Fixed to back high up. 1 larva introduced					1	
,, 25. XXXIX.	Fixed to roof. 1 larva introduced					1	
Tin paper lined compartments in strong light.							
Experiment 26. XLI.	Fixed to roof. 1 larva introduced			1			Only 1 bright green pupa.
,, 27. XLII.	On floor. 1 larva introduced.				1		
,, 28. XLIII.	Fixed to roof. 1 larva introduced			1			
,, 29. XLIV.	On floor. 1 larva introduced.					1	
XLVIII. Tin paper lined cylinder, placed on its side, with clear glass front. Experiment 30.	All on roof. 1 isolated. 7 in somewhat scattered group. — 8 introduced.		8				Very different to the effects of gilt.
L. Opal glass gas-globe. Experiment 31.	3 on glass side near top, near together, but not crowded. 3 on floor (1 deformed, 1 fell off roof). 1 dead on floor. — 7 introduced.				3	3	Tends to produce green pupæ, although not to the same extent as gilt.
LI. Opal glass gas-globe. Experiment 32.	3 on floor (2 (5)). 4 small group high up on side — (1 (2) and 1 (3)). 7 introduced.		1	1	3	2	
LXVII. Compartment lined with orange paper; clear glass front. Experiment 33.	1 introduced (on roof) ..					1	Orange and yellow backgrounds produce bright green pupæ.

C. A company found at Chipping Norton towards the end of July, 1888; compared Aug. 9. Like the larvæ of B, they were changing their last skins when found, and were upon the same bed of nettles. It is probable that they belonged to the same company; 3 of these were intermixed with B in Expt. 6, and it is possible that larvæ of B may have been introduced into Expts. 31 and 32, although this is unlikely.

LXVIII. Compartment lined with yellow paper; clear glass front. Experiment 34.	1 introduced (on floor) ..					1	Orange and yellow backgrounds produce bright green pupæ.
LXXII. Plain wood compartment, with front of red gelatine. Experiment 35.	2 on roof near together. 1 floor. — 3 introduced.					3	Red glass and gelatine produce bright green pupæ when the background is light.
LXXV. Plain wood compartment, with front of red glass. Experiment 36.	1 introduced (on roof) ..					1	
LXXVI. Plain wood compartment, with front of yellow glass. Experiment 37.	4 introduced (on roof near together)..				1	3	Same as 35 and 36, only not quite so strongly in the direction of green pupæ; but this was probably due to crowding.
LXXIII. Plain wood compartment, with front of green gelatine. Experiment 38.	2 introduced (on roof close together)..				1	1	
LXX. Green tissue-paper covered cylinder. Experiment 39.	1 introduced (fixed to roof) ..					1	Same as 35 and 36.
LXXIV. Plain wood compartment, with a front of blue gelatine. Experiment 40.	3 introduced (on roof near together)..			3			Blue light tends to produce darkish pupæ.
On food-plant, on which stock of larvæ were kept. Experiment 41.	2 pupæ low down and shaded on food-plant. Isolated		1	1			The effect was due to shade, for the larvæ are bright green when found on the food-plant in nature.

C. A company found at Chipping Norton towards the end of July, 1888; compared Aug. 9. Like the larvæ of B, they were changing their last skins when found, and were upon the same bed of nettles. It is probable that they belonged to the same company; 3 of these were intermixed with B in Expt. 6, and it is possible that larvæ of B may have been introduced into Expts. 31 and 32, although this is unlikely.

C. A company found at Chipping Norton towards the end of July, 1888: &c.	3 larvæ suspended—mostly low down and in shadow—to food-plant, on which stock of larvæ were fed. These 3 were transferred in Stage III. to a surface of polished Dutch metal in strong light, being pinned up by the boss of silk. Experiment 42.	1 first to pupate				1		Transference in Stage III. apparently produced some effect on two of the pupæ.
		2 second to pupate		1		1		
D. Part of a company found at Oxford about July 22, 1888. Compared Aug. 11. The rest were used in Expts. 77—92.	XXVII. Gilt cylinder. Embossed Dutch metal. Experiment 43.	Unnoted			1	2	1	The (3) was the first to pupate, and may have been affected before experiment.
	LVI. Bright yellow tissue-paper lined compartment. Experiment 44.	On roof; 2 together, 1 isolated					3	Characteristic.
	LXXI. Red glass front to white paper lined box. Experiment 45.	2 first to pupate and fell down	1		1			The first to pupate may have been affected before experiment.
		3 on roof				1	2	
	XIV. Black covered cylinder in complete darkness. Larvæ introduced July 29 (evening). Experiment 46.	Unnoted	1		2		1	Irregular results.
	Transferred for Stage III. from food-plant of stock, to black surface in light. Experiment 47.	....				1		Probably no effect produced.

II. Black paper lined cylinder, placed on its side in strong light. Experiment 48.	19 on upper part of side (roof in this position). 19 introduced	13	6				Strong effects of black surroundings.
I. Black paper lined cylinder, placed open end upwards (roof downwards), and covered with a clear glass sheet, on which the larvæ were densely crowded, with their ventral surfaces in strong light, dorsal in dim light and black surroundings. Experiment 49.	69 on clear glass.	27	14	5	13	10	Irregular results, tending strongly towards the dark forms.
	10 dead on clear glass.						
	7 on black paper sides.	6	1				
	1 dead on black paper sides.						
	87 introduced.						
III. Black paper lined cylinder in darkness. Experiment 50.	13 on black paper roof. 13 introduced	8	1	1	2	1	Irregular results, but tending most strongly towards dark pupæ.
XX. Polished Dutch metal. Experiment 51.	2 on gilt. 2 introduced ..	1				1	As above, but some effect appears to have been produced by the gilt surface during the short periods of illumination; as the proportion of green pupæ is much higher.
XXIII. Dutch leaf. Experiment 52.	2 on gilt. 2 introduced ..	1				1	
XXIV. Dutch leaf. Experiment 53.	1 on gilt.		1				
	1 on glass.	1					
	2 introduced.						
XXIX. Gilt tin box, embossed Dutch metal. Experiment 54.	9 crowded at top of gilt roof (1 dead).	1	3		2	2	
	5 scattered over middle and lower part of gilt.	1			2	2	
	14 introduced.						

3 small cylinders and box in complete darkness, except at 11 p.m. and 9 a.m., when the covering was removed to adjust some other experiments.

E. Two companies of nearly mature larvæ, taken early in July, 1892, near Oxford, and mixed together. The pupæ were compared July 16.

XXII. Small gilt cylinder in strong light. Polished Dutch metal. Experiment 55.	12 on gilt, very crowded. 12 introduced	1	7	1	1	2	Effect of crowding.
XXV. Small gilt cylinder in strong light. Dutch leaf. Experiment 56.	3 on gilt. 3 introduced ..					3	
XIX. Small gilt cylinder in strong light. Polished Dutch metal. Experiment 57.	2 on gilt. 1 dead (dipterous larva — emerged). 3 introduced.					2	Characteristic effect of gilt.
XXI. Small gilt cylinder in strong light. Polished Dutch metal. Experiment 58.	2 on gilt. 2 introduced ..				1	1	
XXVI. Similar cylinder, with the roof more in shadow. Polished Dutch metal. Experiment 59.	3 on gilt. 3 introduced ..		2		1		Some effect produced by the shade of roof.
XVI. Large gold lined cylinder in strong light. Embossed Dutch metal. Experiment 60.	Crowded on upper part of side (roof in this position). 16 introduced				3	13	Interesting to compare effects of crowding with those in a much smaller cylinder, XXII., Expt. 55.
XXXI. Gold lined compartment in strong light. Polished Dutch metal. Experiment 61.	11 crowded on one side of gilt roof. 3 together on the other side. — 14 introduced.	1			2 1	8 2	Characteristic effects of gold somewhat modified by crowding.
XLVI. Silver lined compartment. Silver paper. Experiment 62.	14 distributed over silver top. 14 introduced	8	2		3	1	Very different to gold. The pupæ crowded on the domed roof of XLVII. were especially dark.

E. Two companies of nearly mature larvæ, taken early in July, 1892, near Oxford, and mixed together. The pupæ were compared July 16.

E. Two companies of nearly mature larvæ, taken early in July, 1892, near Oxford, and mixed together. The pupæ were compared July 16.	XLVII. Silver lined cylinder with domed roof. Silver paper. Experiment 63.	17 crowded in silver top of dome.	7	6	2	2		Very different to gold. The pupæ crowded in the domed roof of XLVII. were especially dark.
		1 on white paper floor, with leaves and fæces.		1				
		18 introduced.						
	L. White opal globe. Experiment 64.	10 crowded near top of glass sides 10 introduced					10	Effects like those of gilt.
	LII. Rectangular clear glass box, with a clear glass roof. Experiment 65.	6 crowded in middle of one side.		5		1		Irregular results, inclining towards dark forms.
		4 dead in middle of one side.						
		2 together in one of the black-bound angles of side.	1	1				
		2 together in another of the black-bound angles of side.	2					
		4 on floor with leaves and fæces.	1	1	1	1		
		2 dead on floor with leaves and fæces.						
		1 dead on roof,						
		21 introduced.						
F. The last larvæ of a large company found at Oxford July 17, 1892. Compared Aug. 9.	V. Black paper covered cylinder in strong light, all the paper being *outside* glass. Experiment 66.	2 suspended to roof.	1				1	These experiments were to test whether the effects of gilt and black surfaces were the same when covered with glass. The results show that this is the case, although there was one curious exception in V.
		3 suspended to sides (1 just off the black background and 2 on it).	3					
		1 killed by *Tachina*.						
		6 introduced.						

F. The last larvæ of a large company found at Oxford July 17, 1892. Compared Aug. 9.	XXVIII. A similar cylinder, covered *outside* with polished Dutch metal. Experiment 67.	3 suspended to back (on gold background). 2 suspended to food-plant, close to gold background. 1 dead. — 6 introduced.			1	1	1 2	These experiments were to test whether the effects of gilt and black surfaces were the same when covered with glass. The results show that this is the case, although there was one curious exception in V.
G. Two or three companies found at Oxford in July, 1892. Compared Aug. 9. The larvæ in each experiment were from the same company.	Black covered cylinder, probably I., II., or III.; probably in complete darkness. Experiment 68.	Suspended, probably to roof.	4	4	3		1	Results not so irregular as usual, but conditions not quite certain.
		On floor		2	1			
	Shut up in an oval zinc (corked) pocket box, and therefore in darkness. Experiment 69.	....	3			1	3	Results irregular.
	Placed in 5 small gilt cylinders, XVIII. and others like it (2 in each). Experiment 70.	All suspended to gilt.					2	Some curious exceptions.
	,, 71.					1	1	
	,, 72.			2				
	,, 73.		1				1	
	,, 74.					1		
	In clear glass cylinder, almost filled with yellow spills. Experiment 75.	2 fixed to yellow spills. 2 introduced.					2	Results like those of gilt.
	L. White opal glass, with white paper roof and floor. Experiment 76.	7 fixed to top of globe (not paper).			2	1	4	Results less regular than those of Expts. 31, 32, and 64.
		3 on floor. — 10 introduced.	1		1		1	

The lengths of the stages preparatory to pupation. 1888. *Experiments* 77—92.

I was very desirous of ascertaining the duration of these stages, and of comparing them with *V. urticæ.* A series of experiments, with this object in view, were conducted in the summer of 1888 upon the larvæ of a single company (possibly a few from another company may have been intermixed, although I do not think it is likely), kindly brought me by Miss Bell, having been found near Oxford. Others were used in the experiments already tabulated (D. Experiments 43—47).

The results of frequent examination are shown below: the letter T indicating that the larvæ had sought the top of the case (Stage II.); S, that they had suspended (Stage III.); P, that pupation had occurred. The time beneath each such letter is either estimated or stated without comment; when stated, the change indicated had been actually observed. When no time is quoted, the data were not made use of in calculating the lengths of stages, as was the case when the limits of error were very wide as compared with the interval to be estimated.

(*See Table, pages* 410, 411, 412.)

The results of these observations are worked out below, where the colours of the receptacles and the pupæ are also shown, the latter being carefully compared, Aug. 11, 1888. Two additional experiments (91 and 92) are also included, the calculation being so simple that I did not think it necessary to give the data from which the lengths of the stages were arrived at, as I have in all the other experiments.

(*See Table, pages* 413, 414.)

The 3rd pupæ of Experiments 88 and 89 were transferred immediately after throwing off the larval skin to a white paper floor, close to a gilt back-ground in strong light. The results prove that they had ceased to be sensitive.

The lengths of the stages were subject to the most excessive fluctuation, suggesting that some of the larvæ had quitted their food-plant somewhat prematurely as the result of disturbance, while others left it in the normal manner. It has been already shown, in the case of

Larvæ introduced evening of July 29.	LIII.	LIV.	LV.	LVII.	LVIII.	LIX.	LX.	LXI.	LXII.	LXIII.	LXIV.	LXV.	LXVI.	XLVII.
July 30. 9. 0 a.m.				1 S (say 4 a.m.)					3 S (say 4 a.m.)					
12.15 noon												1 S (say 11 a.m.)		Not examined, 12.15. 1.30 p.m. 1 S 2 T (say 11 a.m.)
2.15 p.m.		1 S (say 1.15)							1 S (say 1 p.m.)					
6. 0 p.m.	1 T (say 4 p.m.)	2 T (say 4 p.m.), food removed before.	1 T (say 4 p.m.)	2 T (say 4 p.m.), food removed.	2 T 1 S (say 4 p.m.), food removed.	3 T (say 4 p.m.), food removed.	3 T (say 4 p.m.), food removed.		Food removed before.		1 T (say 4 p.m.)	2 T (say 4 p.m.), food removed.	2 T (say 4 p.m.)	Food removed.
10. 5 p.m.	1 S by 10.35	2 S (10.5)			1 S (say 8 p.m.)		1 S (say 8 p.m.)	1 T (say 8 p.m.)				1 S 1 T (say 8 p.m.)	2 S (say 8 p.m.)	1 S (say 8 p.m.)
July 31. 9. 0 a.m.				1 P (say 3.30 a.m.) 1 S		1 dead.	1 S (say 3.30 a.m.)		3 P (say 3.30 a.m.)		1 S (say 3.30 a.m.)		1 T (say 3.30 a.m.)	1 S (say 3.30 a.m.)
12.45 noon			1 T (say 11 a.m.)									1 P (1.15 p.m.)		1 P (12.45)

Larvæ introduced evening of July 29.	LIII.	LIV.	LV.	LVII.	LVIII.	LIX.	LX.	LXI.	LXII.	LXIII.	LXIV.	LXV.	LXVI.	XLVII.
July 31. 2.15 p.m.														
3.49 p.m.	1 T (say 3 p.m.)	1 P (4.45)						2 T (say 3 p.m.)	1 P (4.15)	3 T (say 3 p.m.)	1 T (say 3 p.m.)			
6. 0 p.m. to 6.12 p.m.					1 P recently (say 5.30)									
8. 0 p.m.														
10.53 p.m.					1 P (11.5)									
Aug. 1. 9. 0 a.m.	1 P some hrs. (say 4 a.m.	1 P some hrs. (say 4 a.m.		1 S		1 S	1 P some hrs. (say 4 a.m.)	1 S (9.25)			1 T (say 4 a.m.)	1 P some hrs. (say 4 a.m.)	2 P some hrs. (say 4 a.m.)	1 P some hrs. (say 4 a.m.)
11. 4 a.m.	1 S (say 10.0)						1 P (11.0)			1 S (say 10 a.m.)	1 P (about noon).			
Aug. 2. 3. 0 p.m.			2 S	2 P 1 two or three hrs (say 1 p.m.)	1 S	1 P 1 S	1 S	1 P an hour or two (say 1 p.m.) 1 S		2 S		1 S	1 S	1 P
5.35 p.m.							1 P about an hour (say 4.30)	1 S (say 4 p.m.)		1 P (5.54)				

Larvæ introduced evening of July 29.	LIII.	LIV.	LV.	LVII.	LVIII.	LIX.	LX.	LXI.	LXII.	LXIII.	LXIV.	LXV.	LXVI.	XLVII.
Aug. 2. 11.12 p.m.			1 P about an hour (say 10 p.m.)											
Aug. 3. 9. 7 a.m.		1 S dead	1 P many hrs. (say 4 a.m.)		1 P many hrs. (say 4 a.m.)					1 P some hrs. (say 4 a.m.)	1 P an hour or two (say 7 a.m.)	1 dead.		
1.45 p.m.	1 P an hour or two (say 12.0)					1 P an hour or two (say 12.0)								
2.25 p.m.													1 P (2.30)	
3.17 p.m.								1 P only just (3.0)				1 P (3.17)		
7.20 p.m.										1 P an hour or two (say 6 p.m.)				
10.13 p.m.								1 P only just (10.0)						
Aug. 4. 10. 0 a.m.											1 P (10.0)			

Withered leaves and fæces had been left on the floor of LIII., LV., LXI., and LXIII., but in no other compartment.

No. of Experiment.	Receptacle.	Order of pupation.	Position of Pupæ.	Colour of Pupæ.	Length of Stage II.	Length of Stage III.
77	LIII. Lined with deep red paper.	1	Floor.	(1)	About $6\frac{1}{2}$ hours.	About 30 hours.
		2	Roof.	(1)	19 hours (nearly correct).	50 hours (nearly correct).
78	LIV. Lined with deep orange paper.	1	Roof near together.	(5)	.. ..	$27\frac{1}{2}$ hours (nearly correct).
		2		(4)	About 6 hours.	About 30 hours.
		3	Dead.	....	About 6 hours.	
79	LV. Lined with pale yellow paper.	1	Roof near together.	(5)	Together about 78 hours.	
		2		(5)	Together about 65 hours.	
80	LVII. Lined with bright green paper.	1	All on roof.	(3)		
		2		(4)		
		3		(2)	Together about 69 hours.	
81	LVIII. Lined with dark green paper.	1	Floor.	(2)	.. ..	$25\frac{1}{2}$ hours (nearly correct).
		2	Roof near together.	(2)	About 4 hours.	27 hours (nearly correct).
		3		(1)	Together about 84 hours.	
82	LIX. Lined with very pale blue tissue paper.	1	Roof near together.	(4)		
		2		(4)	Together 92 hours (nearly correct).	
83	LX. Lined with light blue paper.	1	Floor.	(2)	About 4 hours.	About 32 hours.
		2	Roof close together.	(3)	Together 43 hours (nearly correct).	
		3		(2)	Together 72 hours (nearly correct).	
84	LXI. Lined with deep blue paper.	1	All on roof near together.	(1)	37 hours (nearly correct).	28 hours (nearly correct).
		2		(3)	Together 72 hours (uearly correct).	
		3		(3)	49 hours (nearly correct).	30 hours (nearly correct).

85	LXII. Lined with dark blue paper.	1	2 roof.	(4)		Uncertain.
		2	1 floor.	(4)		Uncertain.
		3		(4)		Uncertain.
		4	Roof near other 2.	(3)	.. ..	27 hours (nearly correct).
86	LXIII. Lined with light brown tissue paper.	1	Roof near together.	(1)	19 hours (nearly correct).	32 hours (nearly correct).
		2		(2)	Together about 61 hours.	
		3	Fallen.	(3)	Together 75 hours (nearly correct).	
87	LXIV. Lined with white paper.	1	Roof.	(4)	Together 44 hours (nearly correct).	
		2	Floor.	(5)	Together 64 hours (nearly correct).	
		3	Roof, isolated.	(5)	Together about 78 hours.	
88	LXV. Lined with black paper.	1	Roof near together, and near dead larva.	(2)	.. ..	26 hours (nearly correct).
		2		(1)	About 4 hours.	About 32 hours.
		3	Roof, isolated.	(2)	Together at least 90 hours.	
89	LXVI. Lined with black paper.	1	Floor and roof.	(1)	About 4 hours.	About 32 hours.
		2		(1)	About 4 hours.	About 32 hours.
		3	Roof, isolated.	(2)	Together at least 78 hours.	
90	XLVII. Silver paper lined cylinder domed roof.	1	1 isolated.	(1) (3) (3)	.. ..	26 hours (nearly correct).
		2	2 together.		About 9 hours.	About 32 hours.
		3				Uncertain.
91	XVIII. Polished Dutch metal lined cylinder.	1	....	(5)	Together 48 hours (nearly correct).	
92	XIX. Polished Dutch metal lined cylinder.	1	....	(5)	Together 57 hours (nearly correct).	

V. urticæ (see pp. 365—369), that the latter pass through a far shorter preparatory period. In this case the two conditions are probably intermixed, and there is no criterion by which the one can be distinguished from the other. It is therefore impossible to test by these figures the conclusion indicated by the parallel investigation upon *V. urticæ*, as to the protraction of the stages in the formation of dark pupæ. But in other respects the results are extremely interesting, enabling us to contrast the lengths of the stages with those of *V. urticæ*. Stage II. appears to be very short: in 5 cases it lasted about 4 hrs., in 3 about 6, in 1 about 9. Its far greater length in the remaining larvæ was probably a result of disturbance. Stage III., on the other hand, is very long,—about twice as long as its ordinary duration in *V. urticæ*. Stage III. was not subject to great fluctuations, with a single exception of 50 hrs'. duration (probably due to disturbance). On the other hand, it varied from 25½ to 32 hrs., and variations of a rather less extent were quite common. Although there were many larvæ in which the length of this stage was accurately ascertained, they produced (with one exception) dark or darkish pupæ, so that we cannot compare the lengths with those passed through when light pupæ are formed. There is nothing, however, in the table to oppose the conclusions arrived at in the case of *V. urticæ*.

The apparently normal moderate fluctuation in the length of Stage III., as well as its great relative length, suggest that it includes far more of the susceptible period than is the case with *V. urticæ* (and this is proved to be the case further on; see Experiments 94—100). If so, and the conclusions derived from the study of the latter are sound, we must expect that Stage III. will be shorter in light than in dark pupæ of *V. io*, although such a tendency is restricted to Stage II. in the former species, corresponding to the inclusion of the chief susceptibility within its limits.

We may conclude from these experiments that in the production of dark pupæ the normal length of Stage II. is from 4 to 6 hrs., the shorter period being the commoner; while that of Stage III. varies from 25½ to 32 hrs.: longer periods being commoner than shorter ones.

Dates.	Light Surroundings in Strong Light.						Darkness.
	XXV. Small cylinder lined with Dutch leaf. Experiment 94.	XX. Small cylinder lined with polished Dutch metal. Experiment 95.	Resembling XX. Small gold-lined cylinder. Experiment 96.	XXXI. Polished Dutch metal lined compartment. Experiment 97.	LXIX. Yellowish green tissue paper covered cylinder. Experiment 98.	L. White opal globe. Experiment 99.	XVI. Gilt cylinder in complete darkness, covered with rugs, &c. Experiment 100.
July 26, 8. 0 p.m.	Larvæ introduced into this and all the other cases.						
July 27, 1. 5 p.m.	1 suspended.						
,, 2.55 p.m.	....	....	....	2 suspended.			
,, 4.30 p.m.	....	2 suspended.	1 suspended.				
,, 5.15 p.m.	....	....	....	1 suspended.			
,, 7.10 p.m.	....	....	1 suspended.				
,, 7.15 p.m.	....	....	....	....	....	....	5 suspended (not examined before).
,, 10.30 p.m.	No further change in any of these.	....	....	....	....	....	Unexamined.
July 28, 10.15 a.m.	The remaining larva transferred to darkness, and another transferred from darkness here.	....	....	2 suspended. 1 transferred from darkness here.	.... 8 larvæ transferred to darkness (perhaps 1 or 2 of them from XXXI.), and 6 transferred from darkness here.	1 suspended.	3 suspended. The transferred larvæ were evidently towards the end of Stage II., although none had entered Stage III.

Aug. 9. Pupæ compared and tabulated.	1 (5). 1 transferred from darkness. 1 (5) on floor.	1 (5). 1 (3). None transferred.	Both (5). None transferred.	2 first suspended: 1 (4). 1 (3). 1 suspended later: 1 (3). 2 suspended later still: 1 (4). 1 (3). All the larvæ had been crowded together with others that died, and were probably affected reciprocally. 1 transferred from darkness: 1 (3) on floor.	2 transferred from darkness: 1 (4). 1 (5).	1 (4) on glass near top. 4 transferred from darkness: 1 (5). 2 (3). 1 (1). All on floor, except 1 (3) fixed to paper roof. The 3 larvæ close together on floor before pupation.	5 first suspended: 1 (3). 4 (2). 3 suspended later 1 (4). 2 (3). One of the latter had fallen, but is probably to be placed in this category. 9 transferred from gold, white, and green surroundings in light towards end of stage II.: 1 (4). 1 (3). 1 (2). 6 (1).

Effect of cold upon duration of stages and colours of pupæ. Experiment 93. 1892.

Although the experiment described below was unsuccessful, I think the method employed may be useful if lower temperatures are obtained, and I therefore give a brief description of it.

It has already been pointed out that larvæ (at any rate of *V. urticæ*) pass through longer preparatory stages when they produce dark pupæ. I was therefore anxious to test whether dark pupæ would be formed in bright surroundings if the stages were protracted by some other cause, such as cold. A number of similar bottles were lined with black and with gilt paper, in the form of a back-ground covering half the circumference and a roof. The latter was made by covering the bottom, the bottle being inverted when in use. Some of these bottles were sunk beneath the surface of water in a large glass vessel, the water being constantly changed so as to maintain a uniform temperature of 16° C. This was but little lower than the air of the room, but the high specific heat of water would cause it to produce more effect upon the larvæ. If, however, the temperature was sufficient, the effect would be beneficial rather than the reverse, and this was probably the case. It would be well to repeat the experiment, using ice to obtain the lowest temperature compatible with the process of pupation. This I was unable to carry out last summer, being much away from home at the time.

The results only serve to confirm those already obtained by the use of gilt and black surfaces in a strong light. Four larvæ belonging to the same company were placed in each bottle. The pupæ were compared Aug. 19, 1892.

In air, two black-lined bottles contained 7 dark pupæ, but they were dead, and it was impossible to state their degrees of colour with precision; one gilt bottle contained 4 bright green pupæ, evidently (5)s.

In water, two black-lined bottles contained 4 dark pupæ, like those in air; while five gilt bottles contained 11 green pupæ, evidently (5)s.

Transference and comparison Experiments to ascertain the susceptibility of the preparatory stages. Experiments 94—100. 1891.

A few larvæ, probably the last of a company, were found at Oxford, July 26, 1891. Being full-fed the experiments were arranged the same evening, about 8 p.m. They were divided into 2 lots, one of which was placed in gold, green, or white surroundings, in light; the other in gold surroundings in complete darkness, except when examined.

By the morning of July 28 (10.15), 11 larvæ were suspended among those exposed to light, and, as all appeared to be equally mature, it may be assumed that the remaining 9 were very near suspension, *viz.*, the beginning of Stage III. They were, therefore, transferred to darkness for this stage and the remaining part of Stage II. At the same hour 8 of the larvæ in darkness were suspended, and the remaining 8 were transferred to light for the rest of the period before pupation. The following table represents the course and results of the experiments.

(*See Table, pages* 416. 417.)

The results of these experiments are best shown by another method of tabulation.

Pupal Colours.	(1)	(2)	(3)	(4)	(5)	
In darkness for the whole period before pupation ..		4	3	1		= 8
Transferred from bright surroundings in light to darkness for Stage III. and end of II.	6	1	1	1		= 9
Transferred from darkness into gilt surroundings in strong light for Stage III. and end of II.			1		1	= 2
Transferred from darkness into green surroundings in strong light for Stage III. and end of II. ..				1	1	= 2
Transferred from darkness into white surroundings in strong light for Stage III. and end of II. ..	1		2		1	= 4
In gilt surroundings in strong light for the whole period before pupation			1	2	4	= 10
In white surroundings in strong light for the whole period before pupation				1		= 1
						36

This table proves, so far as is possible with so limited a number of individuals, that the sensitive period, during which the pupal colours are determined, is later in this species than in *V. urticæ*. Similar transference experiments (Trans. Roy. Soc., *l. c.*, p. 360) in the case of this latter species proved that Stage II. is the most sensitive part of the period before pupation. This table shows that in *V. io* Stage III. is probably far more important in this respect. In fact the results obtained, when this stage and the end of II. alone were passed through in certain conditions, were practically uniform with those witnessed when the larvæ were exposed to the same conditions for all three stages. There is one marked exception in the case of the dark pupa formed in white surroundings. The larvæ which were transferred into darkness formed even darker pupæ than those which were exposed throughout to this condition.

This high sensitiveness, during Stage III., harmonizes very well with the results obtained from Experiments 77—92, which showed that the stage is of extreme relative length in this species. In writing this paper from the notes taken at the time, as soon as I found the great difference between this species and *V. urticæ* in the relative lengths of the stages, I anticipated that the transference experiments would, when tabulated, lead to the conclusion indicated above. It is probable that the great length of Stage III. has caused the point of greatest susceptibility to be shifted into it. It has been shown (*l. c.*) that this period is somewhat sensitive, probably in its earliest part, even in *V. urticæ*. It is likely that the great extension of this earliest sensitive period accounts for, at any rate, the chief part of the difference between the lengths of Stage III. in these two species of *Vanessa*.

The results are also interesting in confirming the previously described effects of the various environments made use of, and in showing the influence of darkness.

Conflicting Colour Experiments. Experiments 101—103. 1892.

I was most anxious to repeat the experiments already described in the case of *V. urticæ* (see pp. 391—397), and thus, from the behaviour of this most sensitive species, to throw further light upon the physiology of the process, or, at any rate, to gain confirmation.

Some small experiments had already been made, and these had seemed to show that the freshly-formed pupa is certainly not sensitive, and that the larva, if transferred during Stage III., may be susceptible (see Expts. 42, 47, 88, and 89 of this paper; also Phil. Trans., 1887, B, p. 318).

In order to expose the anterior and posterior parts of the larval body to conflicting colours for the whole of the sensitive period, the case described on p. 393 and shown in Plate XV., Fig. 5, was made use of. The strips of the two upper rows of compartments were about half as wide as the length (30·0 mm.) of a suspended larva of *V. io*. In each of the 42 compartments a single larva was placed, all belonging to the same company, taken near Oxford towards the end of July. The pupæ were compared August 11, and the results are given in the following table:—

(*See Table, page* 422.)

The results in every way confirm those obtained in the case of *V. urticæ* (see pp. 394, 395), and support the same conclusions as to the probable existence of a nervous mechanism through which the cuticular colours are created or dismissed in response to the stimulus provided by the light reflected from adjacent surfaces. The pupæ are intermediate, tending rather strongly towards the dark side, very strongly in the lowest row of compartments where the black bands were much broader than the gilt. There was not the slightest tendency towards a particoloured pupal surface corresponding to the conflicting stimuli, nor was there any difference in the effects when the head or the tail were exposed to either colour. The *amount* of skin area receiving the reflected light was evidently the decisive condition, the anterior or posterior position of the area being of no importance.

Reflecting on these results, it occurred to me that the dorsal or ventral position of the skin area exposed to reflected light might be of more importance; for when the larvæ rest on some surface, during Stage II., the dorsal half of the body is but slightly exposed to reflected rays as compared with the ventral half.

In order, therefore, to test the relative susceptibility of dorsal and ventral surfaces, another form of case was constructed. The larvæ were placed separately in shallow

Experiment 101.

	Positions of the Pupæ.	Pupal Colours.					
		(1)	(2)	(3)	(4)	(5)	
Two upper rows with gold and black bands equally wide.	Fixed to junction of bands, head on black, tail on gold	1	1	1			
	Fixed to glass opposite this level	2		1	1		
	Fixed to junction of bands, head on gold, tail on black	2					
	Fixed to glass opposite this level			3			
	Fixed to middle of gold; head and tail on gold, body on black		2				
	Fixed to glass opposite this level		1				
	Fixed rather above middle of gold; much of tail and little of head on gold, body on black	2	1		1		
	Fixed from rather above junction up to middle of black; head and tail on black, body on gold	2	1		1		
	Fixed to glass opposite this level		2	1			
	Dead pupa in one compartment; position unknown. 1 pupa was unnoted ..		1				
	Totals ..	9	9	6	3	0	=27
Lowest row with narrow gilt and broad black bands.	Head and tail equally on black, body crossed by narrow gold band		1				
	Fixed to glass opposite this level	1					
	Head less and tail more on black, body crossed by narrow gold band	2					
	Tail on most or all of gold band, rest of body on black	3	1				
	Fixed to glass opposite this level			1	1		
	Black alone, but head close to gold floor, which reflected upwards strongly ..			1	1		
	Fixed to glass opposite this level (the position of the (2) *is probable, but not certain)*	1	1				
	Totals ..	7	3	2	2	0	=14

black-lined compartments or cells, 3.6 centimetres wide, 3.8 high (six of them were 6.0 high), and 8 to 9 mm. deep. The black tissue-paper lining sloped from the sides to the back of the cells, so that there were no sharp angles or corners. The frame, bearing 24 of these black compartments, was placed vertically, and covered in front with a sheet of white opal glass, which was turned towards a strong light. Each larva was, therefore, contained in a shallow black chamber with a white front, both black and white surfaces being well illuminated. When a larva suspends itself to a surface, it also rests upon it during Stage II., and even if disturbed by its cramped position it must rest on the surface for so much of this stage as is necessary for spinning the silken boss. It is, therefore, safe to conclude that the pupæ suspended to the glass had spent Stage III., and at any rate part, probably the whole, of Stage II., with the ventral surface closely applied to a white area and the dorsal surface exposed to a black area, only separated by a few millimetres from contact with the larval skin; and conversely with the pupæ fixed to the black compartments.

Mature larvæ belonging to the same company were placed in 21 of the cells at the beginning of August, and 3 belonging to another company rather earlier. Both companies were captured near Oxford. The pupæ were compared August 11. The results are shown below:—

Experiment 102.

(*See Table, page* 424.)

The results are quite clear; they prove that black is far more powerful than white when the two conflict, that there is no local effect of colour upon the skin, but that the whole larval surface is uniformly sensitive, dorsal and ventral alike. The two dull green pupæ, (4)s, found among the 9 dark ones which were attached to the opal glass, may be most reasonably explained by individual susceptibility to white rather than black, and to the greater proximity of the surface which was in actual contact with the larva. It is improbable that they afford any evidence for a more sensitive condition of the ventral area as compared with the dorsal, a view which is hardly compatible with the other results.

Experiment 102.

		Degrees of pupal colour.	1	2	3	4	5
21 pupæ of later company.	Ventral surface of larvæ during sensitive period exposed to black, and dorsal to white.	8 fixed to black tissue paper (attached to the sloping side which was uppermost, and formed the roof, or to the point where this roof joined the back)	4	1	3		
	Ventral surface of larvæ during sensitive period exposed to white, and dorsal to black.	9 fixed to opal glass front	4	1	2	2	
	——	Pupated without fixing, or fell off; so that original position uncertain	3		1		
2 pupæ of earlier company.	Ventral surface of larvæ during sensitive period exposed to white, and dorsal to black.	2 fixed to opal glass front	2				

This experiment thus confirms and extends the conclusions arrived at from the use of the other form of case, indicating that the light acts upon widely distributed nerve terminations in the skin.

The same experiment was also tried with another kind of case. Strips of glass were glued on to a glass-sheet in such a manner as to make compartments 9·6 centimetres high, 2·3 wide, and 1·6 deep below, ·3 deep above. Each row of compartments was closed by a single glass front, thus forming a set of wedge-shaped spaces tapering upwards in the position in which the whole was placed (see Plate XV., Fig. 6). The backs of half the compartments were lined with white tissue paper, and the glass front with black, the other half being treated in the converse manner. They were placed in a strong light, the white surface being in half the instances turned to the light and in half turned away from it.

The compartments tapered so that the larvæ could not reach the top, but suspended themselves somewhere about the middle of either the back or front; the white spots on the black surfaces represented in fig. 6 are the silken bosses. Hence the larval dorsal area was exposed to one surface, while the ventral area was in contact with the other, as in the last experiments, except that here the conditions were more uniform in that each surface could be turned towards the light. All the larvæ belonged to one company captured near Oxford, and the pupæ were compared Aug. 9. The results are tabulated below:—

Experiment 103.

	Degrees of Pupal Colour.	1	2	3	4	5
White surfaces turned towards light, black away from it.	11 fixed to black surface away from light	5	3	3		
	10 fixed to white surface towards light	3	1	4	2	
	3 unfixed or fell off; position uncertain	2	1			
Black surfaces turned towards light, white away from it.	19 fixed to black surface towards light	11	5	3		
	4 unfixed, or having fallen off white; uncertain	1	2	1		

These results entirely harmonize with those obtained in the other set of conflicting colour experiments applied to dorsal and ventral areas. The rather less dark pupæ fixed to the white surface are to be accounted for by the greater proximity of white enabling it to neutralize the influence of the more distant black more completely than when their relative proximity was reversed. But even under the most favourable conditions, the white surface did not produce nearly so great an effect as the black. There were no particoloured pupæ, and no evidence that the ventral surface differs from the dorsal in sensitiveness.

In these experiments we meet with evidence that the larvæ sought black in preference to white surroundings, when placed under the same conditions, and that they also manifested a tendency to seek the side turned towards the light. When both these causes co-operated, *viz.*, when the black surface was turned towards the light, at least 19 out of 23 pupated upon it; when they were antagonistic, about half the larvæ followed the one tendency (to seek black), while half followed the other (to seek the side turned towards the light).

Effect of various backgrounds and screens upon the colour of the pupæ.

It will not be necessary to provide such a detailed analysis of the Experiments already described as in the case of *V. urticæ*, where the number of individuals was much larger and the effect of crowding therefore greater, nor shall I discriminate between the effects of the different kinds of gilt paper employed. But all necessary data are supplied in the account of the Experiments themselves, so that a more detailed analysis can be made at any time. In order to economize space, the comparison of the effects of the various conditions will be given in a tabular form, proceeding from the consideration of darkness, black, brown, white, and colourless surfaces to metallic backgrounds, and from these passing to the colours of the spectrum from red to blue. Percentages will not be calculated for very small numbers and single Experiments.

Reference numbers of Experiments.	Pupal Colours. (1)	(2)	(3)	(4)	(5)	Totals.	Results compared.
Black surface in complete darkness.							Experiment 68 was omitted (see description). The difference between these results and those produced by black surfaces in strong light is far greater than in *V. urticæ*, and resembled the relationship in *Pieris rapæ* (Phil. Trans., 1887, B, pp. 411—414). The colours of the pupæ are very irregular, and do not rise uninterruptedly to a maximum in some part of the scale.
Experiments 5 & 6	5	3	4	4	3	=19	
,, 18 & 19	3	2	6	3	2	=16	
,, 46	1		2		1	= 4	
,, 50	8	1	1	2	1	=13	
Totals..	17	6	13	9	7	52	
Results expressed as percentages of total	32·7	11·5	25·0	17·3	13·5		
Gilt surface in darkness.							Probably some effect was produced by the occasional exposure of the larvæ (see account of experiments). Allowing for this, the results are very similar to the above, and exhibit the same irregularity.
Experiments 51 to 54	5	4		4	6	=19	
,, 100		4	3	1		= 8	
Totals..	5	8	3	5	6	27	
Results expressed as percentages of total	18·5	29·6	11·1	18·5	22·2		
Zinc pocket box (darkness).							
Experiment 69	3			1	3	=7	Results irregular, as above.
Black surface in strong light.							Very uniform results, showing the powerful effect of these conditions in producing dark pupæ. There is one interesting exception.
Experiment 1	2					= 2	
,, 48	13	6				=19	
,, 66	4				1	= 5	
,, 88 & 89	3	3				= 6	
Totals..	22	9	0	0	1	32	
Results expressed as percentages of total	68·8	28·1			13·1		
Light brown paper in strong light.							Although the surface was much less dark than the above, its effects were not very different.
Experiment 86	1	1	1			=3	
White opal glass.							From this point onwards all the backgrounds were subjected to strong light. White surfaces tended strongly to produce the light pupæ, but not so strongly as gilt, although far more so than silver. The white paper and opal glass produced the same effect, corresponding to their similar reflecting powers; for both of them return the rays from all parts of the spectrum.
Experiments 31 & 32		1	1	6	5	=13	
,, 64					10	=10	
,, 76	1		3	1	5	=10	
,, 99				1		= 1	
White paper: Experiment 87				1	2	= 3	
Totals..	1	1	4	9	22	37	
Results expressed as percentages of total	2·7	2·7	10·8	24·3	59·5		

Clear glass.							In the absence of any background of sufficient reflecting power, the pupæ apparently tend towards the commoner darker varieties.
Experiment 65	4	7	1	2		=14	
"Gilt" surface (Dutch metal).							Experiment 55 was omitted (see description). Very powerful effect in producing bright pupæ, 71 °/₀ being the lightest forms. These are the most extreme results obtained in this direction, and contrast very strongly with the effect of silver, probably corresponding to the differences in absorption and reflection of light which make the "gilt" yellow and the silver grey. It was clearly shown in the account of Experiment 67, that the "gilt" surface is perfectly effective when separated from the larvæ by a layer of glass.
Experiment 2					4	= 4	
,, 7 to 13		1	1	5	22	=29	
,, 20 to 25			1	1	4	= 6	
,, 43			1	2	1	= 4	
,, 56 to 61	1	2		8	29	=40	
,, 67			1	1	3	= 5	
,, 70 to 74	1	2		2	4	= 9	
,, 91 & 92					2	= 2	
,, 93					15	=15	
,, 94 to 97			4	2	4	=10	
Totals..	2	5	8	21	88	124	
Results expressed as percentages of total	1·6	4·0	6·5	16·9	71·0		
Silver and tin surfaces.							
Experiment 14			1	1	3	= 5	This surface, bright as it is, tends somewhat strongly to produce dark pupæ rather than light. The difference between the effects of "gilt" and silver is far more pronounced than in *V. urticæ*.
,, 26 to 30		8	2	1	1	=12	
,, 62 & 63	15	9	2	5	1	=32	
,, 90	1		2			= 3	
Totals..	16	17	7	7	5	52	
Results expressed as percentages of total	30·8	32·7	13·5	13·5	9·6		
Deep red paper.							Beginning at the least refrangible end of the spectrum, we find that a deep red background in strong light produces the darkest pupæ. On the other hand, red glass and red gelatine, placed in front of white paper and light wood backgrounds respectively, produce light pupæ. The red gelatine especially gave a very pure light, almost exactly corresponding to the rays chiefly reflected from the red background. The remarkable difference in the effects of the same light will be considered at the end of this comparison.
Experiment 77	2					=2	
Red glass.							
Experiment 36					1	=1	
,, 45	1		1	1	2	=5	
Red gelatine.							
Experiment 35					3	=3	
Deep orange paper.							Passing from a red background to an orange one, which reflects the same rays, with the addition of a narrow strip of orange and yellow, we find an entirely opposite result, the pupæ being bright green.
Experiment 33					1	=1	
,, 78				1	1	=2	

Bright and pale yellow paper.						
Experiment 34					1	=1
,, 44					3	=3
,, 75					2	=2
,, 79					2	=2
						8
Yellow glass.						
Experiment 37				1	3	=4

A yellow background tends most strongly of all to produce the brightest pupæ, not a single exception occurring. In this case the paper reflects the same rays, with the addition of a broad strip of green, and the green-yellow rays are less absorbed. Comparison with the green backgrounds proves that it is the additional yellow rays rather than the green, which are effective. Light transmitted through yellow glass, and reflected from light wood, tends (in this case) in the same direction as the yellow background.

Faded yellowish green tissue-paper.						
Experiments 3 & 4					2	=2
,, 15					1	=1
,, 39					1	=1
						4
Bright green paper.						
Experiment 80		1	1	1		=3
Dark green paper.						
Experiment 81	1	2				=3
Green glass.						
Experiment 16					12	=12
Green gelatine.						
Experiment 38				1	1	=2

Although used as a complete covering, the tissue-paper acted as a background as well as a screen. Its thickness was very irregular, and there were many minute holes, so that a large amount of white light passed through it, and the conditions resembled those of a coloured background in light rather than those of a screen placed in front of a white surface. It reflected chiefly the green rays and most of the red, orange, and yellow, while the blue was much absorbed. It produced bright green pupæ without exception. On the other hand, the bright green paper, absorbing the red, orange, and yellow strongly, and reflecting much of the blue as well as green, produced far darker pupæ; while the dark green, absorbing much of every part except the green (and some of this), tended to form distinct dark pupæ. The green glass placed in front of white paper, and the green gelatine in front of light wood, produced effects entirely opposite to the green backgrounds, although the transmitted light was by no means rich in yellow and orange.

Very pale blue tissue-paper.							The blue backgrounds absorbing more and more of all rays except the blue tend to produce dark pupæ, even the faint blue shade of the tissue-paper being accompanied by some slight effect (compare with white paper). The comparatively slight effect of the darkest blue is almost certainly due to the larvæ having been introduced too late (see account of experiment, p. 410). The effect of a blue screen placed in front of a surface of light wood is not very different from that of the blue background.
Experiment 82				2		=2	
Light blue.							
Experiment 83		2	1			=3	
Deep blue.							
Experiment 84	1		2			=3	
Darkest blue.							
Experiment 85			1	3		=4	
Blue gelatine.							
Experiment 40			3			=3	

It is necessary to say a few words about this comparison of the effects of different parts of the spectrum, and the frequent antithesis between the results of screens and backgrounds of the same colour.

In the conclusions at the end of this memoir the colours of both will be given with greater precision, and their effects on all larvæ and pupæ subjected to them will be compared.

The results of the coloured backgrounds in strong light are perfectly regular: it is clear that the rays which check the formation of dark superficial pigment, and so allow the underlying green derived pigments to be seen, lie in the orange and yellow. The other parts of the spectrum do not seem to interfere with this power except by diluting the effective part of the reflected light. Thus red alone produced dark pupæ, but red with orange and yellow produced green ones: and approaching from the opposite side of the spectrum we see the same thing; for blue alone, green and blue, and green alone, produced dark pupæ, while green, yellow, orange, and red, produced green ones. Similarly white light reflecting all colours produced green pupæ.

These results are perfectly uniform and consistent: they are precisely similar to the behaviour of the *Pieridæ* (Phil. Trans., 1887, B., pp. 427-432), when exposed to similar backgrounds, and to the behaviour of the larva of *Amphidasis betularia*, as regards the production of green varieties (see pp. 355—357). Furthermore, the conditions imposed are in strict accordance with those which obtain in nature. The wild larvæ and those which pupate upon coloured backgrounds are freely exposed to bright daylight. Mixed with this, but immensely diluted by it, are the rays reflected from adjacent surfaces, and the yellow and orange constituents of these reflected rays determine the appearance of green pupæ by checking the formation of true pigment.

We are compelled to conclude from these results and those upon the *Pieridæ* (*l. c.*) that the greens of nature (due to chlorophyll) do not produce their effects in making larvæ and pupæ green, because of their brightest constituent, the green rays, but in virtue of the partially absorbed, but still bright, yellow and orange rays contained in their reflected light. And we must further conclude that if these yellow and orange rays were removed, the green rays, bright as they are, diluted by other reflected rays, and, above all, by the immense preponderance of direct white light, would be unable to check the formation of pigment and produce the green pupæ and larvæ. Diluted in this way, only the orange and yellow possess the power to effect such a change.

When, however, we employ coloured screens the conditions are entirely altered. The larva is not exposed to direct white light, but only to the light transmitted through the screen, and the same after reflection from a light background. Hence the rays fall upon the larval surface in an undiluted comparatively concentrated form, and their efficiency is correspondingly increased, extending beyond the orange into the red and beyond the yellow into the green. The effect begins to die away, however, in the feebler blue rays, even when present in this concentrated state. When screens are employed in this way, it is still the reflected rays rather than the direct transmitted ones which are effective; thus in Experiment 21 upon *V. urticæ* (see p. 376), a box (LXXVII.) with green glass windows and lined with *dark green paper* (the paper similar to that employed in Experiment 81 upon *V. io*), produced dark pupæ; while the same box, lined with *white paper*, produced uniformly bright pupæ of *V. io* (Experiment 16, p. 401).

Here the direct transmitted light was the same, but the amount reflected was different; for white paper returns the whole, while the coloured background only reflects a dim green band out of the transmitted light.

The above explanation corresponds to the fact which is apparent in the last table, that coloured screens, when they differ at all from backgrounds in strong light, only do so by producing green pupæ in place of dark ones, and never dark instead of green.

At first sight the tempting converse explanation of the phenomena is suggested, *viz.*, that the terminal parts of the spectrum, and especially the actinic blue, are instrumental in producing the animal pigments, while the orange and yellow rays merely fail to produce them.

I do not think that such a view can be sustained for a moment in face of the facts already adduced. The common appearance of dark pigmented larvæ and pupæ in complete darkness (and on the blackest backgrounds in light), shows that the pigment is a normal product of the animal organism, entirely independent of the agency of light. Furthermore, the region of the spectrum, by which such formation is normally checked, corresponds to the region of greatest intensity of light, and so supports the view that it acts as a definite stimulus, and not merely passively. All the facts hitherto brought forward (except perhaps the golden forms of *V. urticæ*), support the opposite view, that the pigmented form is the primitive one, and is still produced, as a rule, in the absence of any definite stimulus; but that certain conditions in the life of certain species have encouraged, by natural selection, a special susceptibility to certain stimuli which check the formation of pigment, and so produce an appearance which harmonizes with that from which the stimuli arise.

I am here alluding only to the power of becoming green by the non-appearance of true superficial pigment, and not to the power of altering the colour of the latter as in *A. betularia*, &c. This indicates another complex adaptation which has been already briefly considered (see pp. 353, 356, 359).

3. Experiments in 1892 upon the pupæ of Vanessa atalanta and Cynthia cardui.

A few experiments upon *V. atalanta* are described in my previous paper (*l. c.* pp. 398, 399), and the lighter glittering and darker non-glittering forms are shown in the accompanying plate (Figures 13 and 12, × 2). It is there shown that gilt surroundings, and, to a lesser degree, a clear glass cylinder roofed with white muslin, tend to produce light pupæ, with extremely brilliant metallic spots and patches, but without any suffusion of the whole pupal surface with gold, such as happens in the brightest pupæ of *V. urticæ*. Black surroundings in darkness, on the other hand, produced dark pupæ, with very slight traces of gold. No other experiments were attempted for want of material. The pupæ of *C. cardui* have, I believe, never hitherto been subjected to these experiments.

The following experiments have been conducted upon the larvæ during the past year, and one in 1888. The larvæ were captured in the field, and, as they are always isolated, it is impossible to obtain the product of a single pair of parents as in the gregarious *Vanessidæ*.

Experiment 1. *Black-covered cylinder in darkness.*—A single pupa of *V. atalanta* was suspended from the black paper roof. It was dark from the strong development of a network of black pigment over the whole surface : very slight development of gold.

A single pupa of *C. cardui* was similarly suspended, and was dark, due to the appearance of spots on the dorsal area and abdominal segments, and of a dark network on the wings and limbs. There was not much gold for this brilliant pupa, the dorsal line and lateral stripes glittering but feebly.

These and the other pupæ were compared Aug. 9.

Experiment 2. *Black-covered cylinder in strong light, the black paper being* outside *the glass* (*VI.*).—One pupa of each species was formed under these conditions. As in the last experiment, both were dark, with a slight development of gold.

Experiment 3. *Rather larger cylinder, similarly arranged* (*V.*).—A single dark pupa was suspended from the glass roof. Rather more gold was present than in the last experiments, although but little for the species.

Experiment 4. *Similar cylinder to the last, except that black was replaced by gold* (*XXVIII.*).—Two pupæ were formed, one suspended from the glass roof, and one from the food-plant near the gold background. Both were very light and glittering. A single pupa formed in another gilt cylinder, XXVII., in 1888, was also brilliant.

Experiment 5. *Gold-lined compartment of wooden box* (*XXXI.*).—6 larvæ, found July 17, were placed in these surroundings July 18. The 6 pupæ were scattered over the roof, and were very light and glittering.

Experiment 6. *Silver-lined compartment of same box* (*XLVI.*).—6 larvæ, found July 17, were placed here July 18. The 6 pupæ were distributed as in the last experiment, and were also light varieties, but did not exhibit nearly so much gold. The network of pigment covering the surface was also much stronger.

Experiment 7. *Clear glass lamp-shade almost filled with yellow paper spills.*—1 pupa was fixed to a spill, and 5 to the glass near the spills. All the pupæ, except one dark individual with little gold (on the glass), were light-coloured glittering varieties.

Experiment 8. *Opal glass globe* (*L.*).—6 pupæ, suspended from the glass near the top, were light, with brilliant gold spots.

Some of the larvæ, experimented with as described above, were light varieties, and some were dark. The larval colours were not attended by any special tendency towards the formation of light or dark pupæ. This was also noticed in 1886.

These results indicate that *C. cardui* is also probably sensitive, like the allied species; but more individuals are needed to test this satisfactorily.

In *Vanessa atalanta* dark pupæ are formed in darkness and on dark surfaces exposed to light. The black surface is perfectly effective, even when separated from the larva by a layer of glass. Gilt surfaces produce light and glittering pupæ, and the gilt also is effective outside the glass. Silver surfaces produce far less light and brilliant pupæ, the species resembling *V. io* in this respect. White opal glass and bright yellow paper are very effective, as in the other *Vanessidæ*, subjected to experiment.

Conflicting Colour Experiments, 1892.

A few of these experiments were conducted during the past summer. The pupæ in the compartments of the case already described (see p. 393), and shown in Plate XV., Fig. 5, were compared August 28.

Of two pupæ in compartments of the middle row, one was fixed on the junction of black and gold, the head being on the latter, while the other was fixed below the junction, so that the posterior half of the body was against black, and the anterior half against gold. The first pupa was dark, with very little gold, the second light, and with the gold spots rather developed (the large triangular spot was dull, the anterior part of each dorsal spot somewhat golden). Here, while there is no evidence for local effects, a lighter pupa was formed when a relatively larger surface was exposed to gold than when the surface so exposed was smaller.

Another pupa was fixed to the glass in a compartment of the upper row, with the middle of the body opposite a gold band, the head and posterior part equally opposite black. The pupa was dark, with very little gold.

Two were fixed to the glass of compartments of the same row, with the middle of the body opposite black, the head and posterior end equally opposite gold. One was a light variety with little gold, the other intermediate between a dark and light variety.

A single larva was introduced earlier in the summer into one of the shallow black cells, covered in front with white opal glass, described in the Experiments on *V. io* (see p. 423). The pupa was attached to the glass, and was moderately golden, being rather on the light side of an intermediate variety. This result, with the others recorded above, seems to show that the species has a greater susceptibility to white and gilt surroundings when conflicting with black than is the case with *V. io*. The difference between the effects produced by the two opposite backgrounds when used separately is, however, so much less in *V. atalanta* as to render the species far less suitable for the purposes of this enquiry.

There was not the least evidence for any local influence upon the pupæ, so that the results of these experiments confirm the previous conclusions as to the physiology of the process.

4. Experiments in 1888 upon the pupæ of Vanessa polychloros.

Two larvæ, found near Oxford, were subjected to experiment at the end of July, the pupæ being compared July 31. The larvæ passed all three stages preparatory to pupation under the conditions described below.

One had been placed in a moderate-sized cylinder, covered externally with two thicknesses of black tissue-paper and a roof of the same (IX). This being inverted on a black paper floor, was in almost complete darkness. The pupa (position unnoted) was much darker than the other, with no trace of the gold spots. It was comparable to a dark (3) of *Vanessa urticæ.*

The other was placed in the gilt compartment (XXXI.), and was fixed to the roof. Compared with *V. urticæ* it would be a light (3). The gold spots were present on the metathorax and 1st and 2nd abdominals, although they were not *very* bright, and there was no tendency to spread over the general surface, as is so commonly the case with the brighter forms of *V. urticæ.*

My friend Mr. O. H. Latter also experimented on the same species in 1888, and sent the pupæ to me for comparison, which took place August 15.

Three pupæ, formed in black surroundings in a dim light, were *much* darker than the others, with no trace of metallic spots.

Three pupæ, formed in gilt surroundings in a strong light, were all light varieties, with silver spots on the three usual segments.

The results were very uniform in both sets, and the difference greater than in my experiment. It is likely that the dimly illuminated dark surfaces produce more effect than the same in darkness. This is shown in many experiments on other larvæ and pupæ recorded in this paper.

For a much longer series of experiments made in the same year by the Rev. J. W. B. Bell, see 'Midland Naturalist,' December, 1889, pages 289-90. These results also show a very high degree of sensitiveness in the species. The colours appear to be such as to afford concealment, especially upon irregular dark surfaces of bark or rock.

5. Experiments in 1888 upon the pupæ of Argynnis paphia.

Twelve nearly mature larvæ purchased in the spring of 1888 formed the material of these experiments. When they ceased feeding, the larvæ, divided into two equal lots, were placed in two cases, the one with a white-paper roof, the other with a roof of clear glass, upon which was placed a sheet of black paper.

Black surroundings (seen through glass).—6 pupæ were obtained and compared June 22. They were all dark varieties, with a considerable development of cuticular pigment. The golden spots were as distinct as in the others.

White surroundings.—The 5 pupæ obtained were far lighter, being a light brown with a very slight development of pigment, except in one which was about the same as the lightest of the other lot. There is apparently no tendency towards the suffusion of gilt as in *V. urticæ*, but the 5 pairs of spots, on pro-, meso- and metathorax, and abdominals 1 and 2, are very distinct and bright, although those on the mesothorax are very small.

The pupa is evidently highly sensitive, and the effect upon the pigment is certainly such as to promote concealment.

It is interesting to find a case in which the pigment only is affected by the surroundings, and the glittering spots are equally present in dark and light forms. In this respect the species is at present unique, but no doubt further experiment will reveal the presence of others. In all the *Vanessidæ* the glittering spots are affected by the formation of dark pigment, and tend to disappear in many of the dark varieties.

6. Experiments in 1888 upon the pupæ of Pieris brassicæ and P. rapæ.

Before describing the experiments, it is necessary to give some account of the different colour varieties formed in these two species. In *P. brassicæ* we meet with the following classes :—

" (1). The normal form. In these pupæ the ground-colour is always more or less greyish from the abundance and relative size of minute black pigment spots which occupy depressions in the cuticle. . . . . The large black pigment patches and spots are nearly always abundant. . . . . The ground-colour may be of various tints—greyish green, orange, yellow, or a peculiarly opaque-looking greyish white. The amount of the grey colour, always present, subdues the differences between these tints, so that they resemble each other far more than the above description would seem to imply. . . . . The following subdivisions are well marked, although transitional varieties occur :—

- (α) The darkest forms, with greyish green, orange, yellow, or white ground-colour.
- (β) Intermediate forms, with lighter ground-colour of the same tints, and smaller and fewer pigment patches.
- (γ) The lightest of these forms, with ground-colour still greyish, but the pigment patches very small relatively to (α) or (β).

(2) The last sub-division passes into this variety, in which the ground-colour is an opaque-looking whitish yellow, often with greenish areas on part of the surface, the pigment patches being very small. The greyish hue is lost, because of the minute size of the dots in the ground-colour. Hence the effect is very light. . . . .

(3) A still more abnormal, very well-marked, variety, possesses a deep transparent-looking bluish green ground-colour, in which the minute dots and the large patches are even less developed than in the last degree. An opaque whitish-yellow band, like the ground-colour in (2), occupies the anterior half of that part of the third abdominal segment which is seen dorsally, and extends on to the posterior part of the segment in front; and the dorsal surfaces of the abdominal segments behind the third are often mottled with the same colour. . . . .

The differences between the ground-colours of (1), (2), and (3) are very well-marked. . . . ." (Phil. Trans., 1887, B, pp. 409, 410.)

The words "normal" and "abnormal" are only used above in the sense of usual and unusual in the wild state. Every form is normally produced by its appropriate background, and it is only because the wild pupæ are almost invariably found on stone or brick walls, and on palings, that they assume the appearance of (1)s rather than (2)s or (3)s.

The pupæ of *P. rapæ* are divided into 11 classes, passing from very dark varieties:—*Dark* (1), (1), and (2), through the intermediate forms *dark* (3), (3) and *light* (3), into the various shades of light pupæ, *dark* (4), (4), and *light* (4), and finally into the green *pale* (5) and *deep* (5). I need not describe these further, as there are only 7 pupæ of this species tabulated below. But the full account will be found in my previous paper (*l. c.* pp. 410, 411), and 10 of the varieties are figured in the Plate (figs. 32-41, all × 2), as well as 7 of *P. brassicæ* (figs. 24-30, all × 2).

In the paper I have just referred to, a number of experiments, with papers of various colours, showed a great susceptibility on the part of these *Pieridæ* to reflected light within the limits of the orange and yellow. This light prevented the appearance of superficial pigment, and rendered the pupæ green. I was most anxious to experiment further with screens of coloured glass.

Such an investigation was undertaken in the autumn of 1888, nearly mature captured larvæ of *P. brassicæ* and a much smaller number of *P. rapæ* being placed in the cases described below and fed until pupation. Any conclusions from the results are much weakened by the small numbers subjected to the various conditions, and this was due to the excessive mortality of *P. brassicæ* during 1888 from the attacks of Ichneumons. The pupæ tabulated below are only a fifth of the larvæ introduced, 424 having died from this cause.

The pupæ were compared in the following spring, April 6. They were removed from the cases and placed side by side on white paper, and very carefully compared when subject to the same conditions of illumination.

As regards *P. brassicæ*, the differences between 1 (α), 1 (β), and 1 (γ) were well marked and distinct; but the various tints of ground-colour, orange, whitish, greenish, and yellowish (represented in the table by the letters *o*, *w*, *g*, and *y* respectively), found in each of these divisions were almost concealed by the predominant grey, so that they constitute features of very little importance, and it is doubtful whether it is necessary to mention them at all. But as the distinction was made at the time, I have repeated it. The greenest pupæ, the (3)s, were not transparent-looking like the forms described under this degree in 1887 (Phil. Trans., B., *l. c.*), and they had a greater development of the black patches, and a more dusky appearance over the whole surface. The opaque whitish yellow band crossing the 3rd abdominal was slightly marked or absent, and the green ground-colour was not so deep in tint.

The whole of the experiments are described in the following table :—

(*See Table, pages* 441, 442, 443, 444, 445.)

A more exact statement of the light transmitted through the screens and reflected from the backgrounds will be given in F. Conclusions, where the main results of all such experiments will be compared together.

It is very unfortunate that these experiments on the *Pieridæ*, which were conducted with the greatest care, should have lost much of their value from the death of so great a majority of the larvæ. With five times as many individuals to argue from—and this was the number introduced into the cases—tolerably safe conclusions might have been drawn. Even as it is, the conclusions are probably reliable, harmonizing as they do with those derived from the investigation of *V. io*.

In the latter species, and in the *Pieridæ* in 1886, it was ascertained that the larvæ are sensitive to the orange and yellow rays reflected from the adjacent background, when diluted with other rays from the same source, and an immense preponderance of direct white light. But in the case of *V. io*, it has been shown that when both these causes of dilution are reduced by the use of coloured screens, the larvæ became sensitive to reflected rays which would not ordinarily affect them, *viz.*, from the red rays beyond the orange, and the green beyond the yellow; but blue light, however concentrated, did not appear to affect them.

Let us now apply this conclusion to the experiments described above.

Red glass in front of white and orange paper produced a far greater effect in the direction of green pupæ than is usually produced by red paper in white light.

Yellow glass, in front of backgrounds which reflected the yellow light, produced much the same effects as yellow backgrounds in strong light; in front of non-reflecting backgrounds it produced darker pupæ.

Short description of Receptacles. (see G., Appendix).	Position of Pupæ.	Pupal Colours.					Results and further remarks.
		(1) *a.*	(1) *β.*	(1) *γ.*	(2)	(3)	
LXIV. White paper lined compartment in strong light (clear glass). Experiment 1.	1 on roof.					1	Strong effect of white surface. The pupa was unusually dusky for a (3), and with unusual development of black spots for this degree. Light yellowish band across 3rd abdominal fairly distinct.
LXVI. Similar compartment with black paper (varnished surface). Experiment 2.	1 isolated, roof. 1 isolated, top of side.	1 o 1 o					Both pupæ very dark. Characteristic effect of black, contrasting *very* strongly with that of white.
LXIII. Similar compartment with light brown tissue paper. Experiment 3.	2 separate, roof.	1 o	1 g				The (*a*) very dark. Effect nearly as strong as black paper.
LIII. Similar compartment with deep red paper. Experiment 4.	2 opposite sides, roof.		1 g			1	Both pupæ very grey and dusky for their degrees, and yet distinctly green. The (*β*) was *very* grey, although with slight development of black patches and spots; a very remarkable pupa. The light yellowish band hardly present on the (3). The effect on the (3) is very remarkable, and exactly opposite to that obtained in 1886 with much larger numbers. Red backgrounds usually make both species of *Pieridæ* very dark.
LXXI. White paper lined box with red glass front. Experiment 5.	2 on roof together. 5 on roof separate.		1 o 1 w 1 y	 1 y 1 w 1 o	 1		Decidedly lighter pupæ than those generally produced by red backgrounds. Probably same explanation as that offered in the case of *V. io* (see p. 413).

LXXII. Orange paper lined compartment with red glass front. Experiment 6.	2 on roof together.			1 y	1		The (2) is really intermediate between a (2) and a (3), because of the predominant green patches. Same results as above: the paper reflected the red light.
LIV. Orange paper lined compartment in strong light (clear glass). Experiment 7.	2 on roof together.			2 g			Weak effects in direction of green as compared with the same conditions in 1886, when, however, some of the pupæ were (γ)s, and even (β)s.
LV. Similar compartment with pale yellow paper. Experiment 8.	4 on roof together.			3 o 1 y			
LXXVI. White paper lined compartment with yellow glass front. Experiment 9.	3 on roof together.		1 o	1 y 1 w			Effect much the same as that produced by orange and yellow surfaces in strong light in Experiments 7 and 8.
LXXVIII. Compartment similarly lined and covered. Experiment 10.	2 on roof isolated.			1 y 1 w			
	1 loose on floor.			1 y			
LXXIX. Similar compartment lined with orange paper. Experiment 11.	3 on roof isolated.			1 g		2	Dusky (3)s for this degree. In this case we obtain the usual effect of orange and yellow surfaces. The orange paper was nearly as bright in the yellow light as in the spectrum of white light.
LXXX. Similar compartment lined with darkest blue paper. Experiment 12.	2 on roof isolated.		1 w	1 y			These two backgrounds are nearly the same under the yellow glass, which cuts off the blue rays. It is probable that the difference between these results and those of Experiments 2 & 3 is only another example of the observation that darkness has a smaller effect than a black surface in strong light.
LXXXI.[1] Similar compartment lined with black paper. Experiment 13.	1 on roof.	1 w					
	2 loose on floor.		1 y	1 o			

LVIII. Dark green paper lined compartment in strong light (clear glass). Experiment 14.	2 on roof together.	1 w 1 y					This dark green produced the same effect as with *V. io*, leading to dark forms.
	1 on roof isolated.		1 w				
LXXXII. White paper lined compartment covered with green glass front. Experiment 15.	2 on roof together.		1 o	1 o			Some slight effect was apparently produced.
LXXXIII. Similar compartment lined with red paper. Experiment 16.	2 together.		2 o				This combination gave a very dark background, very little green being visible. Some effect may have been produced on the (γ), or probably the result may be one of the irregularities which often occur in darkness.
	1 separate.			1 w			
LXXXIV. Similar compartment lined with orange paper. Experiment 17.	4 on roof somewhat near together.	1 y		1 g		2	This combination reduced the spectrum to a dim yellow-green band, which nevertheless, in the absence of dilution by other rays, produced marked effects.
	1 on roof rather separate.			1 o			
LXXXV. Similar compartment lined with darkest blue paper. Experiment 18.	2 on roof together.	1 w 1 o					This combination cut off the blue, and left very little. In this case the results are those of a black surface. Comparing these 4 compartments covered with the same glass, we are led to believe that the reflected light is alone serviceable, and that, in the absence of dilution, a very little of it may produce considerable effects.
	3 on roof together.	2 o		1 g			
LXXVII. White paper lined box with large green glass windows in back and front (deeper in tint than the above). Experiment 19.	1 on side isolated.			1 g			Although the glass was deeper in tint, it produced more effect in the direction of green pupæ than in that of Experiment 15. This is probably due to the windows being in back, front, and a small one on the top, instead of only in front. The effect is very much below that produced upon *V. io* (see p. 401).
	1 on roof isolated.			1 g			
	2 on roof together.			2 o			
	2 on small green glass window in roof rather near together.	1 y		1 o			

LIX. Pale blue tissue paper lined compartment in strong light (clear glass). Experiment 20.	2 on roof separate. 1 loose on floor.	1 y	 1 y	1 y			These blue surfaces of three shades produced mostly dark pupæ, harmonizing with their effect upon *V. io* in 1888, and upon *P. rapæ* in 1886. 1 pupa of *P. rapæ* was also present in compartment LXI.; it was a yellowish light (3); such forms were also produced in 1886 by a blue background.
LX. Similar compartment with light blue paper. Experiment 21.	2 on roof together. 2 on roof separate.		2 y 2 o				
LXI. Similar compartment with deep blue paper. Experiment 22.	1 on roof isolated. 1 on back isolated.	1 y	 1 o				
LXXXVII. Red paper lined compartment with pale blue glass front. Experiment 23.	4 on roof together. 1 loose on floor.	1 w 1 w	3 w				The red was much dimmed by the glass, but remained much brighter than any other part of the spectrum. The effects are much like black or red in strong light.
LXXXVIII. Similar compartment lined with orange paper. Experiment 24.	1 on roof.			1 o			This combination cut off the extreme red, and produced general dimming of the light reflected from the paper, but not so much as with the green glass (Experiment 17). Some slight effect was probably produced.
LXXXIX. Similar compartment lined with yellow paper. Experiment 25.	2 on roof separate.			2 o			The glass cut off the extreme red, and dimmed the rest of the spectrum. Conclusion as above. Comparing these three compartments leads to the same conclusion as the comparison of 15—18.

XC. White paper lined box with cobalt blue glass front. Experiment 26.	1 on roof, together with 2 *P. rapæ* in one corner.	1 o					The 4 *P. rapæ* pupæ were a dark (1) apparently pinkish, a dark (3) apparently pinkish, a yellowish light (3), and a yellowish dark (4).
	1 in another corner with 2 *P. rapæ*.		1 y				
XCI. White paper lined compartment with cobalt blue glass (darker than XC.) front. Experiment 27.	2 on roof isolated.	1 o		1 g			
XCII. Similar compartment lined with orange paper. Experiment 28.	2 on roof separate.	1 g 1 w					With two striking exceptions, these results confirm those obtained in the cases of *V. io* (1888), and the *Pieridæ* (1886), for all of them show that dark forms are produced by blue light. These far deeper blue screens left very little light to be reflected from the orange and yellow papers, while the white and blue papers reflected chiefly blue light. The exceptions are such as occur not infrequently in darkness. The (3)s were both dusky for this degree, and the (γ) very dusky.
	1 loose on floor.		1 g				
XCIII. Similar compartment lined with yellow paper. Experiment 29.	1 on roof.	1 o					
	1 loose on floor.					1	
XCIV. Similar compartment lined with darkest blue paper. Experiment 30.	2 on roof together.	1 o				1	
LXXIII. Another compartment lined with orange paper and cobalt blue glass front (like XC. or XCI.). Experiment 31.	1 on roof.	1 o					
XCV. Compartment lined with black and orange paper squares of such a size that a pupa of both species of *Pieris* must lie on parts of at least two of them. Experiment 32.			1 w 1 g 3 o	2 y			2 *P. rapæ* pupæ were also in this case, and were a (2) apparently yellowish, and a pinkish (4). There was not the slightest tendency towards a local distribution of pupal colour corresponding to the contrasted colours on which the change took place. The pupæ are on the dark side of intermediate, and the results support the conclusions reached in the case of the *Vanessidæ*.

Green glass in front of reflecting backgrounds produced far more effect in the direction of green pupæ than green backgrounds (devoid of yellow and orange) in strong light. With non-reflecting backgrounds it produced dark pupæ.

Pale blue glass, transmitting much besides blue, similarly produced far greater effects than blue backgrounds in strong light, when placed in front of reflecting surfaces, but produced the same dark pupæ when the backgrounds reflected but little of the light it transmitted.

Deep blue glass, with one or two exceptions, always produced dark pupæ, and the exceptions were evidently not related to the background, but were simple irregularities such as often occur in darkness.

So far as the experiments go, they point to the same conclusions as those reached in the case of *V. io*.

Conflicting colour experiments.—The results of Experiment 32 (XCV.) entirely confirm those upon *V. urticæ* and *V. io*. They also show that the influence of black was stronger than the strongest antagonistic influence when both were working together upon the same organism; for, out of 7 *P. brassicæ*, 5 were in the darkest class except one.

D. Experiments upon the Cocoons of Lepidoptera.

For several years I have, from time to time, made experiments of this kind, whenever I met with a suitable species.

If the power occurs at all, we should chiefly expect to meet with it in species building cocoons upon the surface of the ground among leaves, sticks, &c., or freely exposed on bark, and, among such species, especially in those which pass the winter in the pupal state. Examples of these are to be found below; but all the experiments upon them have yielded negative results, except those upon the genus *Halias*.

The first three species have been experimented upon during the last few years, but I cannot now fix the exact date.

Cerura vinula.—Some careful experiments were conducted upon this species. The cocoons bear the most remarkable likeness to the surface upon which they are fixed, and I wished to ascertain whether this was entirely due to the abundant admixture of adventitious fragments gnawed off the surface, or in part to the colouring of the silk.

Six or more mature larvæ were placed in glass cylinders (1 in each) standing on sheets of glass; beneath the latter and round the lower half of the cylinder white paper was fixed, so that the larvæ were in brilliantly illuminated white surroundings, and yet were compelled to spin cocoons from the products of the silk-glands alone.

About 6 more were similarly placed, except that black paper was used instead of white.

Under these circumstances, most of the larvæ spun compact semi-transparent cocoons, the product of the glands apparently forming a continuous sheet. Some of them, however, failed to construct cocoons, and only used the secretion to form a covering to the glass floor.

The cocoons varied much in colour, being all shades of brown, but there was no evidence whatever for the existence of any sort of relation to the colour of the environment.

It is clear that the adjustment of colour which occurs in nature is, like that of the cocoons of *H. abruptaria* (see p. 317) entirely due to adventitious particles.

Endromis versicolor.—A single mature larva was placed among some shreds of white paper. It spun a cocoon of normally dark brown silk.

Trichiura cratægi.—Some experiments similar to those described below in the case of *P. populi* were made upon this species, with the same negative results. All the cocoons were dark. I have mislaid the notes with the exact numbers.

Hemaris fuciformis 1889.—Six cocoons were spun in two white paper boxes with clear glass covers, 5 of them being among shreds of white paper. The silk of all was more or less brown, but it varied through all shades from dirty white up to dark brown.

Four cocoons were spun among dark twigs in a box lined with dark tissue paper, also with a clear glass cover. These varied in tint in the same manner.

It seems clear that the species is not capable of modifying the colour of its cocoon into correspondence with its environment.

From the occasional occurrence of dark brown patches on a light brown cocoon, it is probable that the larva stains the completed structure, in the manner described by Mr. Bateson.

Pœcilocampa populi 1891.—Four cocoons were spun among leaves and twigs of *Quercus cerris;* these were quite black on all exposed parts, while two spun between pieces of white paper were not nearly so dark. The blackness is, however, due to something which is not silk, the latter being of a much lighter brown. It probably comes from the digestive tract (for neither the paper nor the leaves or twigs around the cocoons appeared to be gnawed), and has the appearance of bitten up food or fæces. It will be interesting to ascertain accurately what this substance is and why the larva has so much less of it when the cocoon is constructed in the paper. It may only follow from an accidental separation from food just before maturity, or from disturbance. Under any circumstances, there seems to be no question of colour adjustment, for the larvæ in the paper made the most conscientious use of all the material they had, and spread it out so as to cover the exposed part of their cocoons as completely as possible.

Halias prasinana 1892.—I brought forward *H. prasinana* as an example of this power of colour-adjustment in 1887 (Proc. Ent. Soc., pp. l, li). When Mr. Bateson had shown a source of error in interpretation, owing to the effect of disturbance on the larvæ, I felt that this case could no longer be sustained without further experiment, in which such errors were specially guarded against. I have fortunately been able to make a few such experiments during the past autumn, which, so far as they go, entirely support my earlier conclusions.

A few nearly mature larvæ, beaten by Mr. Arthur Sidgwick and myself, were placed, directly after capture, in two cylinders. A twig of oak bearing leaves was placed in each of these, and each of them stood on a perforated plate and had a muslin top. The space around the oak twig was filled in one cylinder with white paper spills, in the other with dark sticks, chiefly of *Quercus cerris.* After this the larvæ were not touched, and it is clear that there is no reason for assuming that the larvæ of one cylinder were more disturbed than those of the other.

White surroundings.—3 cocoons were spun upon the muslin roof, which in this case was a considerable distance from the oak-leaves; 1 was light brown; 2 very light brown and almost white. 3 were spun on the glass side near paper spills *and* oak-leaves. Of these 1 was rather dark brown and two were light brown.

Dark surroundings.—1 was spun on the muslin top, in this case near the oak-leaves but away from the sticks; it was intermediate between the tints last described. 3 were spun on the undersides of oak-leaves in close proximity to the dark sticks, and all these were *dark* brown, far darker than any in the other cylinder. One of them was built low down, and some of the white cotton wool wrapped round the oak twig, where it passed through the hole in the plate, was spun into one end of it, while the ends of 3 dark twigs were also fixed to it. As in many other cases among larvæ and pupæ, where dark and light surroundings contend, the former proved to be more powerful, for the cocoon is as dark as the other two. Another 5th cocoon was fixed to the glass cylinder near the leaves, and closely surrounded by dark twigs. It is very dark brown, just like those upon leaves. Mr. Sidgwick tells me that he has always obtained such dark cocoons upon leaves.

Another kind of experiment was then begun. A very small twig of oak with few leaves was placed in each of two similar cylinders, which were then filled up with fragments of white tissue paper, slightly crumpled. One of these was then covered with a larger darkened cylinder so as to be in nearly complete darkness; the other was left in strong light.

In the latter a single cocoon was spun on the white muslin roof far above the oak-leaves, but closely surrounded by white paper, the corner of one piece being spun into it. It was the whitest cocoon obtained, with hardly a trace of brown. In the other darkened cylinder 2 cocoons were obtained, both spun, 4 centimetres apart, on the muslin roof, the white paper close to them, and abundantly spun into one, the leaves far away. The cocoon on the muslin alone was a slightly deeper shade than that on the muslin roof of the cylinder with dark sticks (*viz.*, intermediate between "rather dark brown" and "light brown"); the other spun on to muslin and paper was "light brown," lighter than the darkest on the muslin top and sides of the cylinder with white paper spills, but darker than the "very light brown" ones on the roof of the same cylinder. It was in fact intermediate between these two tints. Both were strikingly different from the white one in the corresponding cylinder exposed to light.

Hence darkness produced brown and light brown cocoons, under conditions which, with light, produced a white one. Experiments upon other species did not render it probable that darkness would produce very dark cocoons, but that it should produce any effect at all is inexplicable, except on the supposition of a colour which can be modified by the larva as a response to external conditions, and this in a normal manner, and not as the result of disturbance.

I was very anxious to apply the crucial test which suggests itself after reading Mr. Bateson's criticisms. He contends that the dark cocoons are normal, and are always formed in nature by healthy larvæ, and that the light ones are produced by disturbance or the presence of parasites.

If, therefore, a much disturbed larva spun a dark cocoon, or, better still, a larva, which had begun to spin a white cocoon on a white surface, afterwards spun a dark one in contact with the appropriate surroundings, it would be quite impossible for Mr. Bateson's criticism to be sustained.

A larva beaten from birch spun a considerable part of a perfectly white cocoon in a white chip box. A birch-leaf was also spun into the cocoon, but in this case the white surroundings predominated. Mr. Sidgwick has also obtained a white cocoon of this species in a chip box during the present year. The cocoon was opened and the larva removed, and it was then found that two eggs of ichneumons, probably of the genus *Paniscus*, were fixed to one or more of the thoracic segments. In trying to remove one of these with scissors, the larva was rather seriously cut, and bled freely. I therefore desisted from the attempt, and placed the larva in a cylinder with oak shoots bearing leaves. To my surprise, it spun on the glass, including the edge of an oak-leaf in its cocoon, but *every thread of silk spun after its removal was brown,* even including the "ladder" by which it ascended the side of the cylinder. To-day (Dec. 17) I opened it, and found, as I expected, the unfortunate larva shrivelled up, and an ichneumon cocoon lying beside it. Thus a distinct brown (by no means light brown) cocoon was spun by a larva which had been subject to almost every kind of disturbance—removed from a partially constructed cocoon, bearing the external eggs of a parasite, and mutilated.

In this case I think it is probable that the instant change in the colour of the silk, noticeable in the threads of the "ladder," and the framework around and beneath, no less than in the cocoon itself, is probably in some way associated with the irritation to which the larva had been subjected. The case suggests, although it does not prove, a source of the colouring matter other than that provided by an extract from the food, contained in the digestive tract; that is, so far as this species is concerned. It was also certain that in this particular case the silk was not darkened by the larva at some later time.

Another experiment of the same kind did not lead to the same results. A larva had begun to spin a white cocoon in a similar chip box. It had only constructed the platform when it was removed and wrapped in many folds of black net. Here it began to spin a white cocoon, but soon died without completing it. As regards this case, it may be remarked that we have no evidence as yet of the effect of black net or black paper upon normal larvæ of this species, although we should suppose that dark cocoons would be produced.

I think that these experiments, few as are the individuals made use of, prove the existence of some power of colour-adjustment in this genus; for such experiments as were conducted were specially arranged to avoid the sources of error present in the earlier ones.

Then, too, Mr. Tutt's observations upon the allied *H. chlorana* afford very strong confirmation; for it is hard to see how any disturbance of his larvæ, sufficient to account for the colour change, can have arisen. (See 'The Entomologist's Record,' Jan. 15, 1892, pp. 9—12).

Rumia cratægata, 1892.—Two beaten larvæ of this species spun *very* light brown transparent-looking cocoons in pieces of white tissue-paper in the cylinder described above as exposed to light. Both larvæ sought the innermost recesses of the crumpled papers. In the absence of comparison experiments I cannot claim that this evidence proves any susceptibility; but I will keep the cocoons to place beside others obtained in later experiments.

Acronycta tridens, 1892. — A captured mature larva spun a perfectly white cocoon on the muslin floor and among the white pieces of paper of the last-named cylinder. Small holes were gnawed in the muslin and the pieces fixed in the cocoon. It is probable that the cocoon is, in nature, entirely concealed by foreign particles, and that the colour of the silk cannot be adjusted.

Orgyia pudibunda, 1892. — Two captured larvæ spun light yellowish cocoons on the muslin floor and among the white tissue-paper of the cylinder in light, and another spun a similar cocoon among the paper fragments and on the muslin roof of the corresponding cylinder in darkness, no effect being produced by the different conditions.

The light yellow colour and slight opacity appear in this species to be solely due to the larval hairs spun into the wall of the cocoon.

Had I not been disappointed by a dealer, I should have again tested the larva of *Saturnia carpini* during the past season. I have no doubt that Mr. Bateson is right in concluding from his experiments that the colour of the cocoon cannot be adjusted; but I should wish, before feeling absolutely certain of this, to apply what I believe is the most searching test of all, viz., *dark and light surroundings as they occur in nature*, using such materials as chalk, light sand, peat, &c.

In admitting the mistake I formerly made in applying the principle of colour-adjustment to certain cocoons, I still think that it applies to some cocoons, and have now brought forward fresh evidence in proof of this conclusion.

In other respects, the amount of confirmation of my earlier work, and of support extended to principles suggested in it, which I have been able to bring forward in the present paper, has been a source of satisfaction.

E. Experiments upon Lepidopterous imagines, 1891.

1. *Experiments in* 1891 *upon the colours of the larvæ, cocoons, and imagines of Gnophos obscurata.*—I have been anxious to experiment upon this species for many years, but, until 1891, I was unable to obtain the material. I have suggested a probable influence of environment in determining the colours of the imago, which is well known to be light-coloured on chalk, and dark on peat ('Colours of Animals,' Internat. Sci. Ser., pp. 157, 158). The colours of these local varieties are certainly protective; for Mr. W. E. Nicholson, of Lewes, who has had a very wide experience of the species, tells me that the imago always rests upon the bare ground by day, although found on the grass if searched for with a lantern at night. This is equally true on chalk and peat, the moth usually resting on the face of pits or banks, beneath ridges or overhanging tufts of vegetation.

My friend Mr. Merrifield, of Brighton, knowing of my wish to experiment with the species, kindly suggested to Mr. Nicholson to obtain some larvæ for me. I wish to express my sincere thanks to both these gentlemen for their kind help, which enabled me to carry out an investigation I had especially looked forward to, and which was of very great interest, although the results obtained were negative.

I received 20 larvæ from Mr. Nicholson on May 16, 1891. These will be called the larvæ of the "first lot." They were obtained by searching with a lantern on the night of May 14, and all were resting on dry grass bents on a steep chalk bank near Lewes, facing S.W. The ground was very white, and the moth when taken in the neighbourhood is very light; in fact, the bank just mentioned is the best locality for the almost pure white variety of the species.

Mr. Nicholson also sent me 25 more larvæ,—the "second lot,"—captured on the night of May 22 in the same locality.

Although the results were negative, I will give some account of the experiments, for the value of the conclusions depends upon the very great care which was exercised. The same methods may also be of use in other species.

The colours of the 20 larvæ of the "first lot" were carefully compared May 17, before being arranged in the experiments on the same day. The 5 largest were about 21·0 mm. long, and were lighter in colour than the remaining 15, which averaged about 18·0 mm. in length. The amount of colour-variability was not great, but distinct. The various shades of colour are mentioned under the experiments. The 25 larvæ of the "second lot" were very uniform in size, the average length being 18·25 mm.; the colours of these larvæ were also more uniform, but 10 were somewhat darker than the others.

The larvæ were fed on various low-growing plants, such as *Achillea*, sorrel, buttercup, and plantain, as well as on the more well-known food-plants, rock-rose and burnet sanguisorb. They did not eat much, being nearly full-fed when received, and, indeed, some were probably quite mature.

The habits of the larvæ were such as to expose them very thoroughly to the materials made use of in the experiments. Small pieces of chalk scattered on white paper formed the light environments; coal and peat on black paper formed the dark. In both cases the larvæ generally hid under the chalk or coal by day, especially when the food consisted of green leaves. When, however, the rock-rose was employed alone, many of them hid by day among the crowded brown stems in the inner part of the plant.

The experiments were of three kinds—Dark Surroundings, White Surroundings, and Transference Experiments.

Dark Surroundings.

(*See Table, page* 455.)

Light Surroundings.

(*See Table, page* 456.)

Various Transference Experiments and others to be compared with them.

Fifteen of the lighter larvæ (although the difference was not great) of the "second lot" were placed, May 25, in a rectangular glass case (LII. Appendix), with a floor of peat and lumps of coal, standing on black paper (below the glass bottom). They were offered rock-rose alone.

May 27, 7 were on the black net roof, and 2 on the plant, the rest having buried deeply in the loose peat.

May 31, 10 buried, and had made cocoons ; these were transferred as described below (p. 457) ; 1 was on plant, and 4 on roof.

June 22, the remaining 5 had buried, and 1 had pupated. They were transferred as described below (p 457).

Dark Surroundings.

Experiment I.	Experiment II.	Experiment III.
The floor of a large glass cylinder (of about 1000 cc. capacity) was black net resting on black paper; on this floor many small lumps of coal were scattered; the roof was black tissue paper.	Arranged as in I.	Dark Surroundings from May 27. Rectangular glass case (LII., Appendix) with floor of peat and lumps of coal standing on black paper (below glass bottom).
Larvæ of "first lot."	Larvæ of "first lot."	Larvæ of "first lot."
May 17. — 2 of the lightest large larvæ & 3 of the lightest small introduced. *May* 24.—3 escaped. *July* 15.—1 had pupated recently, the other died. *Aug.* 15. — Moth emerged.	*May* 17. — 1 intermediate large larva & 4 intermediate small were introduced. *May* 24.—2 escaped. *July* 7.—1 had spun a slight cocoon, and pupated the following day. *July* 15. — The remaining 2 were nearly ready for pupation. *Aug.* 14. — Moth found emerged. *Aug.* 26. — Moth found emerged.	*May* 27. — 6 of the larvæ lost on May 24 were found on that day, but of course original arrangement was unknown. They were placed between 24th and 27th on rock-rose alone, with white paper floor; on 27th introduced here. *June* 23.—All buried, and 1 had recently pupated. *July* 8.—1 dead. 2 pupæ in cocoons. 1 larva ,, 1 pupa in which imago was developing. 1 missing. *Aug.* 3. — 1 imago emerged. *Aug.* 15. — 2 imagos emerged (1 probably on 14th). *Aug.* 26. — 1 imago had emerged. These last 3 imagos emerged from pupæ in well-made cocoons of peat.

Light Surroundings.

Experiment IV.	Experiment V.	Experiment VI.
White paper floor & roof, with lumps of chalk scattered on former. Cylinder as in I. Larvæ of "first lot," except two.	Arranged as in IV. Larvæ of "first lot," except one.	Arranged as in IV. Offered rock-rose alone until June 23, after which nothing was eaten. Larvæ of "second lot."
May 17.—1 darkest of the large larvæ and 4 of the darkest small ones introduced. *May* 24, morning.—A careful comparison of the I., II., IV. & V. was made, all the larvæ being placed on white paper, with the light falling on the same side of them from the same direction. There were no decided effects to be recognised, but *perhaps* those upon the chalk had become somewhat greyer, and those in dark surroundings a little browner. 2 escaped, and were replaced next day by 2 dark varieties of the "second lot." Fed from this date on rock-rose alone. *June* 22.—1 had spun cocoon under chalk lump, 1 dead. *June* 27.—Larva in cocoon had pupated. *July* 7.—1 dead, 1 spun slight cocoon. *July* 15.—2 pupæ & 1 larva in cocoon. *Aug.* 3.—1 moth emerged. *Sept.* 4.—Another moth had emerged.	*May* 17.—1 intermediate large and 4 intermediate small introduced. *May* 24.—1 escaped, but another was added the following day—a dark larva from the "second lot." *July* 7.—1 larva in a cocoon had just pupated; 3 died about this time. *Aug.* 14.—1 moth emerged. *Sept.* 1.—Another moth had emerged.	*May* 25.—7 out of the 10 darkest larvæ introduced. *June* 13.—1 had spun a slight cocoon under a lump of chalk. *July* 15.—1 had pupated without cocoon. *Aug.* 27.—4 pupæ; the 3 other larvæ had died. *Sept.* 4.—1 moth emerged. The other pupæ died.

Experiment VII. Dark Surroundings throughout; for comparison.	Experiment VIII. Dark Surroundings, then light.	Experiment IX. Dark Surroundings throughout; for comparison.	Experiment X. Dark Surroundings, then light.	Experiment XI. Dark Surroundings, then light.
May 31. — 5 cocoons transferred to another case, with peat and coal resting on black paper. Larvæ still lively, and some quitted cocoons as a result of the disturbance; on June 5 4 were in cocoons, but on 13th and later only 2. One had pupated recently on June 22, and was removed to chalk and white paper (X.). *June* 27. — 1 more pupated, and 3 lying in peat. *Aug.* 7.—1 moth emerged.	*May* 31.—5 cocoons similarly transferred to chalk on white paper. All quitted cocoons; by Aug. 27 all had died without pupating.	*June* 22. — 2 cocoons removed and placed in fresh dark surroundings, as in VII.; on June 27, 1 was in cocoon, and had pupated July 7. The other larva made cocoon, and pupated later, 1 moth had emerged Aug. 26, and another Sept. 4.	*June* 22.—1 pupa transferred and placed as in VIII. amid white surroundings. The pupa was evidently freshly formed: also the freshly formed pupa from VII. was transferred here at the same date. *July* 8.—Opaque appearance of wings showed that imagos were developing. The moths emerged Aug. 3rd and 6th.	*June* 22.—2 cocoons removed and placed as in X. Both died without pupating.
The comparison between the results of VII. and VIII. was intended to test the susceptibility of the pupal stage and prepupational period of larvæ, as contrasted with these periods plus a considerable part of later larval life.		The comparison between IX. and XI. was similar to that between VII. and VIII. In X. the susceptibility of pupal stage alone was tested.		

It has already been stated that there was not sufficient evidence that the colours of the larvæ were modified by the conditions of the experiments.

The colour of silk was variable, being sometimes white and sometimes brown, but there was no evidence for the existence of any power of adjustment. Adventitious particles were so freely used as to render the cocoon very hard to detect. In soft peat the larvæ made their cocoons at some considerable depth, but they also freely spun among loose blocks of chalk on the surface.

The imagines, when carefully compared on a white background, showed not the least tendency towards colour-variation in accordance with the environments which had been employed. Indeed they were, for this species, remarkably uniform, being light grey forms, but none of them extremely white, like the var. *pullata*.

It is clear that there is no susceptibility during the period over which the experiments extended. Either the period was not long enough, or the species is not sensitive in this way. If the latter be the true explanation, it is probable that the local races are to be accounted for by natural selection, the lighter varieties being more conspicuous, and therefore exterminated, in peaty districts, and the darker ones on chalk. Before seriously considering this suggestion, I should much like to repeat the experiments, keeping up the conditions for nearly the whole life of the larvæ. In the *Ephyridæ* we meet with pupæ the colours of which are determined by those of the larvæ. It is conceivable that, in this case, the colours of the larvæ may be modified by environment acting in the usual way during the early stages, and that the imaginal colours may follow those of the larvæ. I should also very much like to know the result of exposing the pupæ to different temperatures, as in Mr. Merrifield's most interesting researches.

F. Conclusions.

1. *The light which effects the chief colour-changes in larvæ and pupæ.*—Great interest attaches to the attempt to define the light rays which constitute the stimulus leading to the colour-changes. Of these we must distinguish two main kinds: (*a*) changes in the colour of

the true animal pigments, leading to various shades of brown, grey, &c.; (*b*) the change to a green colour modified from plant pigments in the food. When such a change of colour is possible, the true pigments are always superficial to the green, and cannot be retained without concealing the latter, the degree of concealment depending on the amount and distribution of pigment. Thus in *A. betularia* the true pigments are chiefly placed in the epidermic cells, the green in the subjacent fat, while in many others the former are in the superficial layer of the cuticle, the latter in the blood or sometimes in the lower layers of the cuticle. But the appearance of the green is not merely the removal of a screen, although this must occur; in some cases, at any rate, it also means the formation of the green colouring matter itself.

In discussing the effects of light it will be important, therefore, to discriminate between (*a*) modifications of true pigment; (*b*) its disappearance, accompanied by a change to green.

I propose to tabulate all the coloured backgrounds made use of in these experiments, and briefly to compare their effects on the species subjected to them in 1886 and in subsequent years. We shall thus be able to form a sound conclusion as to the constituents of a mixed reflected light (like that from leaves) which effect the change, and as to the existence of any common susceptibility on the part of such Lepidoptera to light from a particular part of the spectrum.

I wish to express my warm thanks to my friend Sir John Conroy for his great kindness in helping me to make an accurate statement of the quality of the light reflected from backgrounds and transmitted through screens. His well-known researches in this region of physics rendered his kind assistance invaluable.

The method we employed with the backgrounds was as follows:—The spectrum of lime-light, obtained by the use of a bisulphide of carbon prism, was projected on a white paper screen. The coloured backgrounds were then held so as partly to cover the spectrum, when the rays absorbed and reflected could be determined by comparing the covered with the uncovered part. In many cases, two backgrounds were placed in the spectrum together so that they could be accurately compared.

The effect of the screens upon the backgrounds was easily determined by comparing the effect upon the latter when the former was interposed in the path of the light on its way to the prism, with that of its withdrawal.

The reflecting power of the backgrounds having been thus determined, a few days later the whole process was repeated, and the second set of observations compared with the first. In most cases they agreed: when they did not, we made a third observation. These determinations were made in the laboratory of Balliol College, Oxford.

I propose to consider the backgrounds in the following order:—(1) Dark surfaces, such as black and brown, reflecting very faintly, but from every part or many parts of the spectrum; (2) coloured surfaces, chiefly reflecting particular rays: these will be considered in the order of the spectrum from red to blue; (3) white or bright surfaces (white or metallic), reflecting strongly from the whole of the spectrum.

(*See Table, pages* 461, 462, 463, 464.)

These results all combine to prove the validity of the suggestion made in my earlier paper, that rays from the yellow and orange part of the spectrum are effective in dismissing pigment, and favouring green (or bright) larvæ and pupæ. It seems tolerably certain that it is the yellow and orange rays which, reflected from leaves and shoots, stimulate the larvæ and pupæ to become green. It is shown above that if a red background be offered, pupæ become dark; but if an orange surface be substituted, only differing in reflecting an additional narrow strip of the spectrum, but in that strip including orange and yellow rays, both larvæ and pupæ are strongly influenced in the direction of green, although there is hardly any green in the light which reaches them. I attach less weight to the evidence from yellow backgrounds, because they reflect so much of the spectrum. But the evidence from the green backgrounds is the strongest of all. If the above argument holds good, artificial greens which are strong in the yellow and orange ought to act like leaves and shoots, while those which are weak in this part, although as greens they may be extremely bright, ought to produce dark larvæ

Light reflected from backgrounds.	Effects produced.					
	Larvæ.		Pupæ.			
	Amphidasis betularia.	Other sensitive larvæ.	*Vanessa urticæ*, 1886 and later.	*Vanessa io.*	*Pieris brassicæ* and *P. rapæ*, 1886 and 1888.	Other pupæ.
Black paper. Very faint continuous spectrum. It is probably this faint reflection, not stronger in one part of spectrum than another, which acts as the stimulus and accounts for the difference, which is usually very great, between darkness and black surfaces in strong light, the latter causing the more powerful effects. A dead or varnished surface produces the same results. The dark twigs also made use of may be safely included here.	Dark larvæ: blackness varying with that of background.	Dark larvæ.	Dark pupæ.	Dark pupæ.	Dark pupæ.	Dark pupæ.
Light brown tissue-paper on a background of white paper (LXIII.). Strong general absorption, least in red, becoming almost complete in blue.				Dark pupæ.	Dark pupæ.	
Brown twigs. Very similar to the above, except that no blue is reflected.	Brown larvæ.					
Deep red paper. Only one shade used. Spectrum reduced to red, which is but slightly dimmed. Compared with orange (below), it differs in the absorption of parts about solar line D, and above it.				Dark pupæ.	Dark pupæ.	
Deep orange paper. The only orange paper used. Absorption begins a little above line D, removing nearly all green and everything else. All below D reflected.	Green larvæ.			Green pupæ.	Green pupæ.	
Orange enamel (painted on twigs). Red, orange, and yellow reflected, the rest absorbed. Very similar to spectrum of orange paper, but a little shorter.	Green larvæ.					

Light reflected from backgrounds.	Effects produced.					
	Larvæ.		Pupæ.			
	Amphidasis betularia.	Other sensitive larvæ.	*Vanessa urticæ*, 1886 and later.	*Vanessa io.*	*Pieris brassicæ* and *P. rapæ*, 1886 and 1888.	Other pupæ.
Pale yellow paper. Whole of the blue and very little of the more refrangible end of the green very faint. All the rest as bright as with white paper (LV., LXVIII.; also *Pieridæ* in 1886).				Green pupæ.	Green & intermediate pupæ.	
Bright yellow tissue-paper on a background of white paper. As above, except that the blue and end of green are completely absorbed (LVI.).				Green pupæ.	Green pupæ of *P. rapæ* (Griffiths).	
Bright yellow opaque paper, somewhat deeper and more orange in tint than the last. No perceptible difference in the spectrum. Made into spills; placed in a clear glass lamp-shade.				Green pupæ.		Light & brilliant pupæ of *V. atalanta.*
Green leaves and shoots of living plants. The red and blue rays are much absorbed, but, in the small thickness traversed by the reflected light, the orange and yellow little, and the green hardly at all.	Green larvæ (in nature & in experiments).	Light brown larvæ: greenish brown or green in *Rumia cratægata* (experiment).	Healthy brilliant pupæ (sometimes found in nature).	Green pupæ (in nature).	Green pupæ (in nature); also of *P. napi* (Merrifield).	*V. polychloros* said to be light reddish brown, with metallic spots.
Bright yellowish green tissue-paper (faded). Blue much absorbed, green hardly at all, the rest but little (much in the unfaded paper. LXIX., LXX.; also *Pieridæ*, 1886).			Irregular results: paper in part unfaded; also considerable crowding	Green pupæ.	Green & intermediate pupæ. (Uncertain how far paper was faded).	
Light green enamel (painted on twigs). Green bright; red, orange, and yellow but little absorbed. Blue wanting.	Green larvæ (not very bright).					

Light reflected from backgrounds.	Effects produced.					
	Larvæ.		Pupæ.			
	Amphidasis betularia.	Other sensitive larvæ.	*Vanessa urticæ*, 1886 and later.	*Vanessa io.*	*Pieris brassicæ* and *P. rapæ*. 1886 and 1888.	Other pupæ.
Bright green paper (arsenite of copper). Considerable absorption of red, orange, and yellow, very slight of green; extreme blue absent and the rest dimmed (LVII. and spills).	Light brown & greenish larvæ (probably poisoned by the pigment)			Darkish pupæ.		
Pale bluish green paper. The same paper, rendered paler (probably as the effect of damp), was used with the experiments on *Pieridæ* in 1886. The spectrum, as described in Phil. Trans. (1887, B, p. 430), is very similar.					Dark pupæ, *P. brassicæ;* intermediate *P. rapæ.*	
Dark green enamel (painted on twigs). Red, orange, and yellow darkened, blue wanting; slight absorption of green.	Darkish larvæ predominate.					
Dark dull green paper. Some general absorption, least in green, most in blue, considerable in yellow, orange, and red (LVIII.).				Dark pupæ.	Dark pupæ (*P. brassicæ*).	
Very pale blue tissue-paper, on a background of white paper. Some slight absorption of red, yellow, and orange; the rest of spectrum unchanged (LIX.)				Green pupæ, but not the greenest.	Dark & intermediate pupæ.	
Light blue paper. All blue unabsorbed, and all other parts considerably weakened, but much less so than below (LX.).				Dark pupæ.	Darkish pupæ (*P. brassicæ*)	
Deep blue paper. Great absorption of all except blue (LXI., blue spills).	Dark larvæ.			Dark pupæ.	Dark pupæ (*P. brassicæ*)	

Light reflected from backgrounds.	Effects produced.					
	Larvæ.		Pupæ.			
	Amphidasis betularia.	Other sensitive larvæ.	*Vanessa urticæ*, 1886 and later.	*Vanessa io.*	*Pieris brassicæ* and *P. rapæ*, 1886 and 1888.	Other pupæ.
Darkest blue paper. Very great absorption of all except blue, which was slightly absorbed (LXII., blue spills).	Uniformly very dark larvæ: a deep purplish brown.			Dark pupæ.	Darkish pupæ (*P. rapæ*, 1886).	
White metallic surfaces of tin and silver. These give a strong, continuous spectrum, but the light is reflected regularly, and not much diffused.			Tend to produce light and brilliant pupæ, but not so much as below.	Tend to produce green pupæ, but not nearly so much as below.		*V. atalanta.* Produce light and brilliant pupæ, but not so much as below.
Yellow metallic surface of brass ("gilt") also appears to give a strong, continuous spectrum, but the yellow colour is due to the absorption of blue. Reflect regularly as above. More effect is produced when there is increased diffusion, owing to the surface being irregular.			Produces the lightest and most brilliant pupæ.	Tends very strongly to produce green pupæ.		*V. polychloros*, *V. atalanta.* Produces the lightest and most brilliant pupæ.
White opal glass. Gives a strong, continuous spectrum; the light is diffused.			Tends strongly to produce light and brilliant pupæ.	Tends strongly to produce green pupæ.		*V. atalanta.* Produces the lightest and most brilliant pupæ.
White paper. Spectrum as above.	White larvæ.		As above.	As above.	Light or green pupæ.	*Argynnis paphia.* Very light pupæ (no change in brilliancy).

and pupæ. And this is what has been found to occur. I attach great importance to the colour of copper arsenite in this respect. I hope to try it again on a larger scale, covering it with varnish so as, if possible, to prevent any poisonous effect.

The larvæ and pupæ are probably sensitive to diffused rather than regularly reflected light, the strong effect of "gilt" being explained by its absorption of blue rays, and the consequent greater prominence of yellow, as well as by its power of returning so high a proportion of the light which falls on it. Silver and tin with this same power, but without that selective absorption which gives prominence to yellow, exert a far inferior influence upon these insects. The effect of white paper and opal glass is easily explained on the principles laid down above.

I have hitherto only considered the production of green or bright pupæ and larvæ. But the table of backgrounds at once proves that the case is far more complex in certain species, and notably in *Amphidasis betularia.* These larvæ behave like the pupæ as regards green, black, and orange backgrounds, but entirely differently as regards brown, white, and, to some extent, deep blue. These do not make the larvæ green, but produce a special form of true pigment, in two cases corresponding to the coloured surface which emitted the rays forming the stimulus. It cannot be doubted that these effects also follow from the constitution of the diffused light reflected from the background (see also pp. 353, 356, 359).

The same contention is true of *R. cratægata*, the true pigments of which can certainly be modified, as well as dismissed (see p. 326), and probably of all sensitive larvæ; for it is unlikely that the great difference between the dark and light browns is only a question of quantity of pigment.

We are justified in concluding that a larva of a species which possesses this power of adjustment (as regards pupa or larva) is effected, during the sensitive period, by certain constituents of the diffused light reflected from surfaces in its *immediate* neighbourhood, diluted as it is by other constituents, and far more by the direct white light which falls on every part of its surface. It is sensitive to this very small proportion of effective rays, and can, as a response to the stimulus, produce true pigment, or dismiss it and become green, or in some cases can alter the constitution of the former so as to produce a variety of tints, each of which is more or less appropriate to some form of natural environment.

The use of coloured screens obviously alters the case entirely, for the larval surface is thus exposed to far more concentrated rays from certain parts of the spectrum.

The screens employed were kindly described for me by Sir John Conroy. I quote his determinations below:—

Red gelatine. — "Transmitted light. Red. The absorption begins abruptly on the less refrangible side of D at about a wave-length of 604, and extends through the remainder of the spectrum."—Receptacle LXXII. (see G, Appendix).

Although the light was thus a very pure red, the larvæ of *V. io* formed distinct green pupæ when exposed to it upon a reflecting background. In this concentrated form, red rays have the power only possessed by yellow and orange under more normal conditions.

Red glass.—"Transmitted light. Red and some yellow, together with a little green and a trace of blue. Light of wave-lengths between about 589 (D) and 559 strongly absorbed."—Receptacles LXXI., LXXII. (at one time), LXXV.

Green pupæ of *V. io* were similarly formed beneath this screen, and much lighter pupæ of *P. brassicæ* than those usually produced by a red background.

Yellow glass.—"Transmitted light. Red, yellow, and green. Slight general absorption of the red, yellow and green, and strong absorption of all the blue rays."——Receptacles LXXVIII. to LXXXI., and LXXVI.

Green pupæ of *V. io* were similarly formed, and intermediate or light pupæ of *P. brassicæ.* When the background reflected hardly any of the transmitted light, the pupæ of the latter were darker.

Green gelatine.—"Transmitted light. Red, yellow, and green. Some general absorption through red, yellow and green, and strong absorption of rays of wave-length greater than 462."—Receptacle LXXIII.

Green pupæ of *V. io* were similarly formed.

Green glass.—"Transmitted light. Some red, yellow, and green. Light of wave-length greater than 605 and less than 501 strongly absorbed. The rays between 605 and 576 considerably absorbed."—Receptacles LXXXII. to LXXXV.

Results with *P. brassicæ* much the same as with the yellow glass, but more irregular, and on the whole darker.

Green glass.—" Transmitted light. Green. Light of wave-length greater than 572 and less than 517 strongly absorbed."—Receptacle LXXVII.

Pupæ of *V. io* formed upon a reflecting background behind this screen, which is far more complete than the last, were uniformly green. Pupæ of *V. urticæ* formed behind it upon a feebly reflecting background were dark. Pupæ of *P. brassicæ* under the former conditions were intermediate.

Pale blue glass.—" Transmitted light. Some red and yellow, the yellow-green, and most of the blue. The extreme red below 645 absorbed, a faint absorption-band from 605 to 584, and a slight continuous absorption above 548."—Receptacles LXXXVI. to LXXXIX.

When in front of backgrounds which reflected all transmitted light, except the blue, intermediate pupæ were produced; when with a background which reflected only the red, the pupæ were much darker.

Blue gelatine. — " Transmitted light. Some red, and the yellow-green and blue. Slight general absorption of the red, and an ill-defined dark band from about 608 to 578."—Receptacle LXXIV.

Intermediate pupæ of *V. io* were formed behind this screen.

Blue cobalt glass.—" Transmitted light. The extreme red; yellow-green; a small amount of green, and the blue. Strong absorption of light of wave-length between 702 and 576, and also of wave-length greater than 553; the upper limit of this strong absorption too ill-defined to be measured."—Receptacles XCI. to XCIV.

With certain exceptions, dark pupæ of *P. brassicæ* were formed behind this blue screen upon reflecting and non-reflecting backgrounds alike.

Blue cobalt glass.—" Very similar to the above, but it transmits rather more light."—Receptacle XC. Receptacle LXXIII. was (at one time) covered with this glass, or that last described.

Same effects upon *P. brassicæ*.

The results, upon the whole, supported the argument already given. *V. io* is evidently far more sensitive than *P. brassicæ*, and I greatly regret that so few of the latter were subjected to the conditions described above.

On the whole it is probable that, when the direct white light is cut off by a screen, and in some cases the mixed reflected light reduced by the same means, the larvæ, when resting on reflecting surfaces, are sensitive to a larger part of the spectrum, comprising the red on the one side, and the green on the other, but not the blue.

In talking the matter over with Sir John Conroy, he suggested that the heating effects of the rays may have something to do with their power; for he informed me that the usual opinion as to the superior heating properties of the red and ultra-red rays is mistaken, and only holds for dispersed light, when the smaller refrangibility of these rays leads to crowding in a given area. Under the conditions of these experiments, he tells me that the yellow rays possess the greatest heating power.

But if it were a question of temperature, it is very difficult to understand why the effects of reflected light are not completely subdued by those of direct light. Nor is there any evidence that accessory conditions which must *greatly* affect the temperature of the larvæ, such as the amount of sunshine, have any influence upon the result. Upon the whole it appears far more probable that nerve-terminations in the skin are directly affected by the radiant energy, and, in most cases, are especially sensitive to those vibrations which appear to affect animal life most powerfully.

Some conclusions from the experiments on larvæ.—I have here brought together some of the chief results of the shorter experiments.

Regularly dimorphic forms, with intermediate varieties rare or wanting, are never, as far as our present knowledge extends, susceptible to surrounding colours, while variable species tend to be so. In this respect *Geometra papilionaria* is very interesting, being susceptible when variable during its youth, but not in advanced stages, when it is dimorphic. Among the *Geometræ*, so many of which are strongly susceptible, we meet with well-marked dimorphism in the genus *Ephyra*, which is apparently not affected by surroundings.

Noctuæ are far less sensitive than *Geometræ*, both in relative numbers and in the effect produced in the most marked cases. The most susceptible *Noctuæ*, the *Catocalidæ*, are purely arboreal forms, like the majority of

Geometræ, and specialised, like the latter, for concealment among twigs and on bark. It was the knowledge of this specialisation which led me to test for that further protection which is afforded by the power of colour-change.

The other larvæ (*Smerinthus*, *Sphinx*, *Aglia*) which I have tested are very inferior to the genus *Catocala* in this respect, but from what Col. Swinhoe tells me, it is evident that some of the Indian *Sphingidæ* are highly susceptible.

There may be a most extraordinary fluctuation in the amount of susceptibility within the limits of the same genus (*Catocala*, and in the pupæ of *Papilio*).

In *Geometræ* alone have distinct green larvæ been produced by these experiments. Probably the great majority of these larvæ are sensitive. Out of 11 species, many of which were selected at random, all but one have proved to be so.

There is no evidence that the results acquired by one generation can be transmitted to the next (*Rumia*, *Crocallis*). The susceptibility is essentially an adaptation to the fact that the individuals of each such species are liable to find themselves in different environments, so that any bias from the experiences of the past would of course be injurious, unless the earlier and later surroundings happened to correspond.

In the case of *R. cratægata* the test for hereditary effects was as complete as it could be in one generation.

Concerning the time which is necessary before the colour-changes begin to appear—

Some effect	was	produced	in 8	days in young	*G. papilionaria.*
,,	,,	,,	8	,,	*C. electa.*
Much	,,	,,	12	,,	*C. elinguaria.*
,,	,,	,,	14 about	,,	*M. montanata.*
,,	,,	,,	11 ,,	,,	*C. elocata.*
,,	,,	,,	13 (or less)	,,	*H. abruptaria.*
,,	,,	,,	17	,,	*R. cratægata.*
,,	,,	,,	8	,,	*A. betularia.*

When carefully watched for, the changes are sometimes seen to occur quite suddenly (*C. elinguaria*, *R. cratægata*, 1886, II.).

The effects cannot be reversed by reversing the surroundings for a short time (*C. elinguaria*, *H. abruptaria*, *A. betularia*).

When the conditions are uniform, the response to environment does not necessarily destroy individual variability, but the most powerful forms of environment, when applied to highly sensitive species, very nearly do away with it.

If the environment be mixed, there does not appear to be any instinctive knowledge leading the larvæ to rest only on appropriate objects. Thus, if they have become green, and are beyond the power of change, they will nevertheless rest on brown twigs in preference to leaves, if offered to them.

The instinct of these *Geometræ* is to rest upon twigs under any circumstances, and this is probably the reason why so small a proportion of twigs produces so great an effect (*A. betularia*, 1889). Contact, or at all events the closest proximity, is required to effect the change. Although they are so much more susceptible to brown surroundings when these are mixed with green, there were *no* exceptions among 105 larvæ which in 1889 became green among leaves and shoots.

The effects produced on the larvæ do not influence the colours of the moths (*A. betularia*).

Darkness does not produce so great an effect as black surroundings in strong light (*A. betularia*, *R. cratægata*, *C. elinguaria*). Overcrowding tends to produce dark larvæ (*A. betularia*, *R. cratægata*).

In the case of *R. cratægata* and *A. betularia*, there is direct evidence of the power being efficient in concealing the wild larvæ.

The larvæ are probably chiefly sensitive at the time when they quit the leaves and first begin to rest on the twigs.

The protective significance of the colour changes.—Looking at the results here recorded, as a whole, there can be no doubt about these changes being such as to promote concealment. In the majority of the larvæ the only possible change appears to be from dark to light brown or greenish brown. But the latter are far less conspicuous on the leaves than the dark varieties would have been, although they are not nearly so well concealed as the latter upon the dark twigs. When the larvæ of any one of these species hatch upon a tree, or part of a tree, with a great abundance of young green shoots, their susceptibility would certainly lead them in the direction of concealment. It by no means follows that the power is useless in certain species because it leads to more perfect results in others. Concerning the latter, no one who has once seen the larvæ of *A. betularia* or *R. cratægata* upon their food-plants in the field, can doubt about the meaning of the changes in colour which they undergo.

The pupæ of many species have now been tested, and only in the case of one of them (*V. urticæ*) has any doubt been expressed as to the efficiency of the change in promoting concealment. The cases of *Vanessa io* and the *Pieridæ* (including *P. napi*) are nearly as clear as those of *A. betularia* and *R. cratægata*, and the same may be said of a few S. African species tested by Mrs. M. E. Barber, Mr. Roland Trimen, and Mr. Mansel Weale. The changes of *Vanessa atalanta* and *V. polychloros* certainly lead in the same direction; and there is not that excessive development of the golden appearance in the lighter forms which, in *V. urticæ*, is thought by some to be a conclusive argument against the protective significance of the change.

In *Argynnis paphia* we have a very interesting case. There can be no doubt about the change being strongly in the direction of concealment, but the metallic spots (which are not very large) are equally present in both dark and light pupæ. The ancestral relationship of the *Argynnidæ* to the *Vanessidæ*, as shown by Dr. Dixey in the comparison of the wing markings, suggests the possibility that the metallic spots are an ancestral feature of both pupæ which can be removed from the darker forms of *Vanessidæ*, but remain in the lighter ones, while they persist in both varieties of at least one species of *Argynnis*. In this respect it is interesting to note that the position of each metallic spot can generally be detected by its lighter colour in the dark pupæ of such species as *V. polychloros* or *V. atalanta*.

I must now consider the case of *V. urticæ* at greater length, because of the arguments brought forward by Mr. Bateson in a recent paper (Trans. Ent. Soc., Lond., 1892, pp. 212, 213).

This writer, in the first place, attempts to cut away the foundation of an interpretation based on natural selection, by arguing that there is no struggle for existence during the pupal stage of this species.

It is interesting to note the antagonistic objections which Mr. Bateson and Mr. Beddard urge against the protective efficiency of colouring, the one holding that enemies are purely imaginary, and the other that they are so supremely successful that no concealment is of avail against them.

No one feels more keenly than I the truth which Darwin so constantly urges in his letters, that we are profoundly ignorant of the conditions of existence of almost every organism. But Darwin never used this ignorance as grounds for the assumption that enemies are "imaginary" for any part of the life of any animal. He rather felt that the enemies were apt to be under-estimated than over-estimated. I have great hope that this part of the evidence for natural selection will be tested as severely as possible by those who believe in the doctrine; for there seems to be little chance of such work being forthcoming from those who attempt to depreciate it. It is very much easier to assume that enemies are imaginary than set about a searching enquiry into the conditions of existence as they affect any one animal. But such expressions of opinion have their value in stimulating those who consider them to be eminently unscientific to obtain direct evidence.

I have for a long time wished to undertake such an investigation myself, but one man alone cannot do much, especially in the vast field of observation which must be covered in order to obtain adequate direct evidence. This paper and my other works are an indication that I have not been idle. In the hope that others may be induced to work at the subject, I will therefore mention some lines which I think would lead to useful results.

Larvæ of such species as *A. betularia* might be liberated upon plants which harmonize and upon others which do not harmonize with their colour. Only one larva should be placed on each branch, not many branches on the same tree should be employed, and the trees should be widely separated. The larvæ might be liberated at the last ecdysis, so that their colours would remain nearly constant. They should be observed and noted twice a day. If they disappeared at once, allowance would have to be made for wandering, but if they settled down on the branch, there would be no reason for suspecting them of this.

Pupæ may be observed more satisfactorily. Large stones could be placed in a case with a *few* mature larvæ, and when two or three (not more) pupæ were suspended to each, the stones could be removed to the borders of some wood or field and noted twice a day. This would be a fairer test than a garden. In this way the pupæ would be accessible to such probable enemies as insectivora and rodents. In other comparison experiments light pupæ could be fixed to dark stones and *vice versâ*. This test could be satisfactorily applied to many species, and other objects made use of as well as stones.

With regard to imagines, we first require to find where many of them conceal themselves at night and in rainy weather. This could be accomplished by tracking the butterflies at dusk, marking the spot where they finally come to rest, and again examining it at night with a lantern. Butterflies bred in confinement could then be placed at night in natural and unnatural situations, observed in half an hour to see whether they had moved, and again observed and noted in the morning before they begin to fly. The same kind of observation could be made with hybernating species.

In the meantime, however, there is some very strong indirect evidence which is worthy of attention. Assuming that a female *V. urticæ* lays 300 eggs, every pair of butterflies would be represented by 300 offspring in the next generation, were it not for the deaths which ensue at some period of development. Owing to this cause, however, we know that, on the average, they only produce 2 mature offspring to take their place, and themselves become parents. The extinction of 298 out of 300 means a severe struggle for existence, and does not support the assumption of "imaginary" enemies during any stage or in any week, especially when we remember that there are two or more generations in a year. And, contrary to the commonly received opinion, I should maintain that extinction is least during the first of the three stages. The larvæ are perfectly exposed and obvious during their whole lives, and we know their conditions fairly well; of the pupæ, in nature, and the imagines, when concealed, we know comparatively little. The larvæ have been proved to be distasteful to certain insect-eating animals, and the persistence of large colonies through the whole of larval life proves that they are not subject to much extermination from this cause. Their chief foes at this period are dipterous and hymenopterous parasites, but the deaths are not nearly so numerous as might be inferred from Mr. Bateson's experience. In 1886 I experimented on 700 larvæ belonging to many colonies (the exact numbers can be ascertained in my paper, Phil. Trans., *l.c.*), and in 1888 upon the many hundred larvæ tabulated in this memoir; but I am quite sure that the deaths from this cause did not come to anything like 10 per cent. The *Tachina* larvæ nearly always emerge before the *Vanessa* pupates, and are quite obvious, together with the dead or dying larvæ. The proportion of deaths in *V. io* was not widely different.

There are great differences between the colonies in this respect, as is well shown by Mr. Bateson's experience of 5 or 6 deaths to 1 survival. It would be very interesting to observe whether there are any individual differences in the methods employed by these larvæ in keeping off their insect foes, so as perhaps partially to explain why some colonies are almost swept away, while others are nearly untouched. I hasten to anticipate Mr. Bateson's objection by stating that this suggestion is not intended as a "basis for argument," but as a stimulus to observation. Everyone who has observed these larvæ must have noticed the twitching of the wild larvæ when disturbed, and how readily the movement becomes concerted and common to a whole detachment of a colony. This is probably one of their methods of defence against such foes.

The numerical argument alone drives us to the two remaining stages for the chief extermination, and it is impossible, on these grounds alone, to admit that the pupal stage, short as it is, can escape.

Mr. Bateson considers that the theory of the protective significance of colour has only been "applied to the case of these pupæ by an indiscriminate extension of deductions made in other cases fairly enough, as, for example, in that of the larvæ of *A. betularia*." And yet we can only suppose that these latter are large enough to be the prey of insect-eating vertebrates for about the length of the pupal period of the *Vanessa;* and, as for concealment, the latter would be far more perfectly hidden were it not for walls and palings, which are not a strictly natural environment.

When we also remember that, wherever they pupate in a natural environment, it is almost certainly within reach of small insectivorous or omnivorous mammals, which can hardly have the chance of reaching the larvæ of *betularia*, we are led to connect their more complete concealment with their greater dangers. In speaking of "more complete concealment," I refer to the result, however brought about,—to the instinct which leads them to scatter and hide we hardly know where, as well as to the colour and shape.

Mr. Bateson states that he would have been less surprised if the golden pupæ of *V. urticæ* had been brought forward as examples of warning than of protective coloration. But the most prominent feature of the latter is the habit of adopting a conspicuous position or attitude; for this, even more than the colour, displays the organism to its enemies. In the pupæ of *Euplœa core* we probably have an example in which the metallic appearance has this significance, but it is always freely exposed, and, as Mr. Minchin tells me, most conspicuous, and can be seen from a great distance. It is impossible to say this of *V. urticæ* as it occurs in nature. Again, I have experimented with *V. urticæ*, and find that the most fastidious of all insect-eating animals I have come across, a marmoset, devoured the golden varieties, one after the other, with the greatest relish.

Mr. Bateson argues that the golden varieties cannot be protective because they are conspicuous against certain artificial backgrounds, which nevertheless stimulate their production. It is strange that he should have employed such an argument, considering that I showed, in 1887, strong reason for believing that only *some* of the constituents of the reflected light are effective in the production of the far more perfectly concealed green pupæ of *Pieridæ*. If the yellow constituent of the light reflected from leaves is proved to be efficient rather than the green, it by no means follows that the power is not directed towards concealment, because yellow backgrounds are effective in producing green pupæ.

The same argument would deny any "'attempt' on the part of the animal to approximate to the colour of its surroundings" to the larvæ of *A. betularia*, and the pupæ of *V. io* and the *Pieridæ*, because all these become bright green against orange backgrounds. And yet Mr. Bateson admits such an "attempt" on the part of *betularia* (*l. c.*; p. 212).

Mr. Bateson fails to apprehend that if the pupæ *had* resembled the various artificial backgrounds, it would have been the strongest blow against the theory of the protective significance of the change. We can hardly imagine the production, under the theory of natural selection, of adaptation to surroundings which had never before been met with in the life of the species, and it would be clear that we had to deal with some other power. I have no prejudice against my own discoveries that I should seek to minimise them; but the chief reason why I have failed to see in them what some others have believed they have seen, *viz.*, the indications of some new power in the moulding of species, is because I have only been able to produce those changes which can be produced by a natural environment. Even the golden pupæ of *V. urticæ* form no exception; for healthy individuals are known to occur, although rarely, upon the leaves of nettles.*

Mr. Bateson does not seem to see that his opinion that the golden form is conspicuous is really at variance with his contention that the pupal susceptibility does not tend towards concealment; for, in nature, the susceptibility is chiefly employed in checking the production of this very form. Until my experiments, the golden pupæ were little known, except when diseased.

We have seen that the colour-changes of all species proved to be susceptible certainly tend towards concealment, *V. urticæ* being alone disputed; that the protective green and dark forms of *V. io* certainly correspond physiologically to the gilded and dark forms of *V. urticæ*, while the dark forms of the latter are certainly protective; for the pupa would be dark on a

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* Mr. Merrifield tells me that, during the last week of August, 1892, he found about 50 pupæ of *V. urticæ*, evidently belonging to one company, suspended to the stalks of nettles, or sometimes of other plants growing with them. All were entirely golden, and all produced ichneumons. A few days later Mr. Merrifield found a colony of over 200 nearly mature larvæ, and among them about a dozen pupæ, also on the nettle-stalks. These were equally golden, and about half produced imagos, the remainder being ichneumoned (one died from some unknown cause). See also Experiment 63, p. 382.

dark stone, and light on a light one. Which is the more improbable hypothesis,—that the light form, now nearly always withheld, originally possessed a protective significance like the dark form of the same species, and the corresponding light form of the nearly allied *V. io*,—or that one form of one species stands on an utterly different biological level from all the rest? I think it far more likely that "all zoological science will be thrown into confusion" by such gratuitous assumptions than by any attempt I have made to suggest, with all due caution, a possible environment in the past history of the species with which the golden form may have harmonised.

I still hold, and on far stronger grounds than formerly, that all the changes are, or were, in the direction of concealment; that the golden appearance applied chiefly to some former environment, or one which may still exist in other countries; that in one species (*V. io*) it has been almost replaced by the green variety, while it has been hidden by the habits of another (*V. atalanta*), and removed from the darkest forms of all *Vanessidæ;* that in *V. urticæ* it occasionally occurs on the natural food-plant, and is still protective, in that it is less conspicuous in this situation than the dark form would have been; but that the latter is so far more effective in promoting concealment that the larvæ have developed a strong instinct to wander, and are rarely found on the nettle-plants in the healthy state.

This whole question is considered by Mr. Bateson to be an "unprofitable field for study": he may have found it so; but any attempt to limit the investigations of others by the barrenness of his own experience, cannot be tolerated. It has been the guidance of this hypothesis of the protective value of the colour-changes which has chiefly directed me to seek the forms which are most suitable for the purposes of this enquiry, and to apply the most efficient experiments, and so to accumulate facts which have an interest far beyond their relation to the hypothesis itself.

G. APPENDIX.

An account of the various receptacles used in the experiments on pupæ. (C.)

In the experiments upon pupæ a great variety of receptacles was employed. Inasmuch as the crowding of the pupæ greatly affects their colour, it is necessary to give the approximate dimensions. A full description will now be given, in which each receptacle will be denominated by the number which represents it in the experiments described in the paper.

A. Black Surroundings.

I. A low wide glass cylinder, 1·86 decimetres diameter, ·91 high; lined inside with black tissue-paper (1 layer), and 2 layers for roof.

II. A very similar cylinder, 1·76 decimetres diameter, ·77 high; lined with 1 and covered with 2 thicknesses of black tissue-paper; roof, 2 thicknesses.

III. A very similar cylinder, 1·6 decimetres diameter, 1·0 high; lined and covered as in II.

These 3 cylinders were sometimes employed in strong light, being placed on their sides, and the open end closed by a sheet of clear glass. The upper part of the side then became the roof, and the paper roof a black background.

In other experiments they were used in darkness, being placed on their open ends on a floor of black tissue-paper. In many cases the darkness was rendered complete by a further covering of mats, rugs, &c., although it was tolerably complete when these were omitted.

IV. A tall glass cylinder, ·825 decimetres diameter, 1·79 high; lined inside for half the circumference with a single layer of black-tissue paper; roof, 2 layers of same.

This was always used in strong light, the clear half of the cylinder being turned towards the window.

V. A similar cylinder, with the black background fixed *outside* the glass, the roof consisting of a single layer of tissue-paper gummed on to a sheet of glass, which was turned glass-downwards on the open end of the cylinder.

This was always used in strong light, and it was employed to determine whether a black paper surface was as effective when separated from the larvæ by the thickness of the glass.

VI. A similar arrangement, with a domed cylinder, like those described below.

VII. This was one out of three compartments in a wooden box, measuring 3·3 decimetres high, 1·43 wide in front, 1·85 wide at back, 1·25 deep; lined throughout with black tissue-paper.

A clear glass sheet closed the front, and this was always turned towards a strong light.

The remaining black receptacles were always used in darkness, sometimes with the addition of rugs and mats, sometimes without. They were always placed open end downwards on a black tissue-paper floor, except when the larvæ were fed in them, and this was only very occasionally.

VIII. A cylinder similar to IV., covered with 2 layers of black tissue-paper, and a roof of the same.

IX. A smaller cylinder of the same kind, ·71 decimetres diameter, 1·53 high; covered and roofed as in VIII.

X. A cylinder, probably of the same size as IX., or perhaps IV., possibly domed like the succeeding ones. In any case, the covering was as in these.

XI., XII., XIII., XIV. These 4 cylinders were ·70 decimetres diameter, 1·98 high, with the upper end domed, so that the diameter was reduced to rather less than half that of the lower end. They were all covered with 2 layers of black tissue-paper, and had roofs of 2 or generally many more thicknesses.

XV. A wooden box, about 3 decimetres long, 2 wide, and $1\frac{1}{2}$ deep; lined with black tissue-paper, and inverted on a floor of the same.

B. "Gilt" Surroundings.

The various so-called gilt papers employed were in all cases covered with "Dutch metal," a mixture of copper and zinc, the proportion of the former metal being very high. Three kinds of such gilt paper were employed:—(1) The metal had been applied in the form of "leaf," and bore a strong resemblance to true gold-leaf. The surface was very bright and golden, but was not highly polished. This was the only gilt-paper made use of in my earlier experiments, and erroneously described as "gold-leaf" in my paper (Phil. Trans., *l.c.*, p. 324). It will be spoken of as "Dutch leaf." (2) A very highly polished metallic surface, often tending to become tarnished and copper-like. This will be called "polished Dutch metal." (3) A very similar metallic surface, apparently not quite so brilliant, with an embossed pattern on it. This will be called "embossed Dutch metal."

I wish to express my thanks to Mr. W. W. Fisher and Mr. Walker for kindly analysing samples of these and the "silver" papers employed, in the Oxford University Laboratory.

XVI. A low wide cylinder, 2·38 decimetres diameter, 1·02 high; lined with embossed Dutch metal, and a roof the same. The external surface of cylinder and roof was covered with one layer of black tissue-paper, and this receptacle was sometimes used for testing the effect of gold surroundings in darkness. It was then covered with rugs, mats, &c.

At other times it was placed on its side, with the open end closed by a sheet of clear glass directed towards a strong light.

XVII. A very similar cylinder, 2·42 decimetres diameter, 1·16 high. Half the internal surface was lined with polished Dutch metal, and one open end closed by the same. When placed on its side the gilded surface was uppermost and formed a roof, while the covered end formed a background. When placed on its open end the latter formed the roof.

This and the succeeding gold receptacles were always used in a strong light, unless otherwise stated.

XVIII., XIX., XX., XXI., and XXII. Five small cylinders, all about 6·2 centimetres diameter, 8·4 high. They were always placed on the open end on a floor of white paper or polished Dutch metal. A polished Dutch metal roof sloped from the front part of the upper end to the back part of the lower end (in the position placed during use), so that little more than half the capacity of the cylinder was available for larvæ. The clear front of the cylinder was placed so as to face a strong light.

XXIII. A similar cylinder, lined in the same manner with Dutch leaf.

XXIV. and XXV. Two similar cylinders, also lined with Dutch leaf, but the roof sloped much less steeply from the front to a point about $\frac{2}{5}$ down the back of the cylinder in the case of XXIV., about $\frac{1}{5}$ in XXV., so that nearly the whole of the capacity was available (about $\frac{4}{5}$ in XXIV., and much more in XXV.). Below the level at which the roof joined the back, the latter was lined with the same gilt paper, extending round half the circumference of the cylinder.

XXVI. A rather taller cylinder (1·01 decimetres), of the same diameter. The sides were gilt two-thirds round, and the gilt paper brought together to form a ridged roof with very sloping sides, the ridge running from back to front. There were deep shadows in the higher part of the roof within the ridge, which was nearly 2 centimetres higher than the cylinder. About two-thirds of the capacity was available. Owing to the gilt lining extending so far round the cylinder, the clear front was reduced, and the gold surface much less illuminated than in the other small cylinders, XVIII. to XXV. The gilding was polished Dutch metal.

XXVII. A tall cylinder, the same dimensions as IV.; lined in the same manner as XXV., with embossed Dutch metal, so that nearly the whole capacity was available.

XXVIII. A similar cylinder, treated exactly like V., except that the black paper outside the glass was replaced by polished Dutch metal.

XXIX. A tin box, 2·35 decimetres long, 1·07 wide and deep; placed on end with glass sheet in front. There was a sloping roof, as in XVIII., so that about half capacity was available. On the floor and a small area of bottom of sides the bright tin surface was exposed, but the rest was gilt. The gilt paper was crumpled to make cavities and reflections in all directions. The gilding was embossed Dutch metal.

XXX. A large flat wooden box, about 3 decimetres high, 6½ wide, 6 centimetres deep; lined in upper part (standing on 1 long side) with polished Dutch metal, and a clear glass front.

This box was subsequently divided into 14 compartments, lined with various colours (see LIII. to LXVI.).

XXXI. Compartment of wooden box. 2·2 decimetres high. 1·14 wide, 1·06 deep: lined with polished Dutch metal (1888, with Dutch leaf in 1886 and 1887) everywhere, except the lower end which formed the floor, and this was covered with brown paper. The gold-paper back curved gradually into the roof and sides, and both roof and back were well crumpled. Nearly all the space available. Clear glass front.

XXXII. This was another compartment in the same wooden box which contained VII., 3·3 decimetres high, 1·4 wide in front, 1·2 wide at back. 1·25 decimetres deep. The roof sloped back at an angle of 45° to increase the illumination, and was "coffered" (12 recesses divided by ridges). There were 2 shelves on each side, flat above, making an angle of 45° with the side of the box below. The whole was lined with embossed Dutch metal, except the floor, which was covered with brown paper. Clear glass front.

XXXIII. The third compartment in the same wooden box, similar to XXXII., except that the lining was polished Dutch metal.

XXXIV., XXXV., XXXVI., XXXVII., XXXVIII., XXXIX. 6 out of 12 small compartments in a wooden box, each 9·2 centimetres high, 5·4 deep, and varying from 4·5 to 3·4 in width. All were lined throughout with gilt paper, XXXIV., XXXV., and XXXVI. being polished Dutch metal, and the other three partly of this and partly embossed Dutch metal. A single sheet of clear glass covered the front of these and the remaining 6 compartments.

C. Silver and Tin Surroundings.

The silver-paper employed was of two kinds:—(1) Covered with true silver, having a very bright, but not polished surface: this will be called "silver paper"; (2) covered with metallic tin. The surface was more polished than the silver, but not nearly equal to tin-plate. This will be spoken of as "tin-paper." In addition to these, boxes of tin-plate were employed, and will be spoken of merely as "tin boxes."

XL., XLI., XLII., XLIII., XLIV., XLV. The 6 remaining compartments of the same box, of the same dimensions, except that the narrowest was only 2·8 centimetres wide. XL. was lined with silver, and the rest with tin paper.

XLVI. The second compartment in the same box which contained XXXI. The dimensions and arrangements were the same, except that gilt paper was replaced by silver-paper. Previous to 1888 this compartment had been lined with Dutch leaf.

XLVII. A glass cylinder 1·69 decimetres diameter, and 1·60 high. About two-fifths of the circumference at the bottom was lined with silver paper, which widened to half the circumference at the top. The silver paper roof was domed, the summit extending nearly 1 decimetre above the top of the cylinder. All the silver-paper was well crumpled. In use, the cylinder was placed on a white paper floor, and the clear part of the circumference was turned towards a strong light. The silvered back was highly illuminated, but the inner part of the dome was in shadow, especially its upper part.

XLVIII. A low wide glass cylinder, 2·63 decimetres diameter, ·812 high. Arranged as in XVII., except that tin-paper was used, and was crumpled, and that roof and back passed gradually into each other. Nearly all space available.

XLIX. A bright tin box, similar to XXIX., except that it was not lined with paper, the surface of the tin-plate being used as an environment; another similar box was also employed in 1887.

D. White Surroundings.

L., LI. Two white "opal" glass gas globes, 1·78 decimetres high, placed, narrow opening upwards, on a sheet of white paper. The upper open end was provided with a white paper roof.

E. Clear Glass.

LII. Rectangular clear glass box about 2·6 decimetres high, and 1·6 square in section, with open end uppermost, and covered with clear sheet of glass. All angles and edges bound with black paper. Placed in strong light.

This was also used in the experiments on *G. obscurata*, when the clear glass roof was replaced by perforated zinc.

F. Surroundings of various colours.

LIII. to LXVI. 14 compartments of a wooden box, 12 of them 8·3 centimetres wide, 1·35 decimetres high, and 6·0 centimetres deep; 2 of them (LIII. and LXV.) were rather wider (9·1 centimetres), In the centre of the back of all, except LVII., LIX., and LXIV., a small cardboard box (8·7 centimetres high, 4 wide, and 1·7 deep) was fixed with its long axis vertical. In LVI., however, the box was 7·8 centimetres wide. Each box was covered with paper similar to that which lined the compartment in which it was contained. The object was to provide irregularities of surface in the shape of angles, shelves, &c. Clear glass sheets covered the whole box, which was turned towards a strong light. The colours of the compartments were as follows:—

LIII. Deep red.
LIV. Deep orange.
LV. Pale yellow.
LVI. Bright yellow (tissue-paper).
LVII. Bright green.
LVIII. Dark green.
LIX. Very pale blue (tissue-paper).
LX. Light blue.
LXI. Deep blue.
LXII. Dark blue.
LXIII. Light brown (tissue-paper).
LXIV. White.
LXV. Black (dead).
LXVI. Black (bright; varnished surface).

The colours of LIII., LIV., LV., and LXII., are figured in my previous paper on the colours of pupæ (Phil. Trans., *l. c.*, Plate 26, figs. 16, 17, 18, and 21). The colours of all, except LVI., LIX., and LXIII., were very opaque and uniform; those of the three compartments just mentioned, being produced by tissue-paper pasted on to white paper, were far less regular, and contained a much larger admixture of white light. This was especially the case in LIX., in which the white light greatly preponderated.

These compartments were used in the experiments on *Pieridæ*, as well as *Vanessidæ.*

LXVII. and LXVIII. 2 compartments of a wooden box, 1·08 decimetres wide, ·61 high, ·47 deep, covered in with a clear glass front.

LXVII. was lined throughout with deep orange paper, similar to LIV.

LXVIII. was lined throughout with pale yellow paper, similar to LV.

LXIX. A glass cylinder, 7·2 centimetres diameter, 1·57 decimetres high, covered with 1 thickness of faded yellowish green tissue-paper, and roof of same. Much white light passed through, as well as green. The paper was the same as that figured in Phil. Trans., *l. c.*, Plate 26, fig. 19.

LXX. A glass cylinder, about 1·1 decimetres high, and rather less diameter than LXIX. Similarly covered and roofed.

G. Light transmitted through Coloured Glass or Gelatine.

LXXI. A wooden box, 1·7 decimetres wide, 1·75 high, and ·6 deep, lined with white paper and covered with red glass ("flashed," *viz.*, a clear glass with a red surface).

Used for *Pieridæ* as well as *Vanessidæ.*

LXXII. to LXXVI. Five compartments of a wooden box; 3 of them 7·5 centimetres wide, 9·3 high, 4·8 deep.

Of these, LXXII. was covered with a sheet of red gelatine, the interior being plain light coloured wood. When the *Pieridæ* were experimented with, the interior was lined with deep orange paper, and the gelatine replaced by red glass, like that of LXXI.

LXXIII. was covered with a sheet of bright green gelatine, the interior plain. In the experiments on *Pieridæ*, the gelatine was replaced by blue glass, and the interior lined with deep orange paper.

LXXIV. was covered with a sheet of blue gelatine, the interior being plain (not used with *Pieridæ*).

LXXV. was only 2·15 centimetres wide (otherwise similar). It was covered with red glass like LXXI., the interior plain (not used with *Pieridæ*).

LXXVI. was 2·22 decimetres wide (otherwise similar). It was covered with a sheet of yellow glass, the interior plain. When used with *Pieridæ* the interior was lined with white paper.

LXXVII. A wooden box, 2·53 decimetres square, 1·53 deep, standing on one side. Quite three-fourths of area of top and bottom (2 largest sides in the position in which it stood) covered with green glass, and a small window of the same in upper side (roof). Lined everywhere with white paper.

When used for *Vanessa urticæ* it was lined with dark green paper. Afterwards, lined with white paper, it was employed for *Pieridæ*, as well as *Vanessa io*.

The remaining receptacles were employed for *Pieridæ* alone.

LXXVIII. to LXXXI. Four compartments of wooden box, covered with a single sheet of yellow glass.

LXXVIII.: 9·5 centimetres wide, 1·0 decimetre high, and 6·0 centimetres deep; lined with white paper.

LXXIX.: Similar, only 1·1 decimetres wide; lined with orange paper.

LXXX.: Similar to LXXVIII.; lined with blue paper.

LXXXI.: Similar to LXXIX.; lined with black paper.

LXXXII. to LXXXV. Four compartments of wooden box, covered with a single sheet of green glass. The compartments were all about 1·22 decimetres wide, 1·44 high, and ·81 deep.

LXXXII. was lined with white paper.

LXXXIII. was lined with red paper.

LXXXIV. was lined with orange paper.

LXXXV. was lined with blue paper.

LXXXVI. to LXXXIX. Four compartments of the same box, covered with a single sheet of pale blue glass. The compartments were rather wider than those just described (1·28 decimetres), but otherwise similar.

LXXXVI. was lined with white paper.

LXXXVII. was lined with red paper.

LXXXVIII. was lined with orange paper.

LXXXIX. was lined with yellow paper.

XC. A wooden box, 2·12 decimetres square and ·62 deep, lined with white paper, and covered with a sheet of blue cobalt glass.

XCI. to XCIV. Four compartments of wooden box, covered with a single sheet of blue cobalt glass, considerably deeper in tint than that of XC. The compartments were all about 1·0 decimetre square and ·6 deep.

XCI. was lined with white paper.

XCII. was lined with orange paper.

XCIII. was lined with yellow paper.

XCIV. was lined with blue paper.

XCV. Compartment of wooden box (1·09 decimetres wide, 1·35 high, and ·56 deep), covered with a sheet of clear glass, and lined throughout with black and orange squares of equal size, regularly alternating. Each was 12·5 mm. square, and thus a size which ensured that a pupa of *Pieris brassicæ* and *P. rapæ* would lie on at least two of them.

Explanation of Plates XIV. & XV.

PLATE XIV.

All the figures are drawn of the natural size, which in all cases is that of the larvæ either mature or approaching maturity.

Figs. 1, 2, and 8 were drawn by Miss Cundell; figs. 9 to 17 by Mr. J. T. Murray; the remainder by the writer.

Fig. 1.—The larvæ of *Hemerophila abruptaria*, reared among green shoots and leaves of lilac (food-plant), upon which they are shown in the figure.

Fig. 2.—The larvæ of the same species fed on the same food, with which a number of very dark twigs were intermixed. The larvæ are seen at rest on a branch of *Quercus cerris.* The attitude of the resting larvæ in this and fig. 1 is not quite natural. A cocoon is shown on the right side of the base of the branch. Its strong resemblance to the bark is produced by the number of small fragments gnawed off and woven into it.

Fig. 3.—A dark larva of *Rumia cratægata* brought up among dark twigs. A bluish "bloom" is seen upon it.

Fig. 4.—Another dark larva of the same species brought up under the same conditions. The "bloom" covers more of the surface, and a small patch of green colour is seen behind the dorsal humps.

Fig. 5.—A very black larva without "bloom," brought up under the same conditions.

Fig. 6.—A brownish green larva of the same species, fed on the same food-plant (hawthorn), but brought up among green shoots and leaves. A bluish "bloom" is present.

Fig. 7.—A light brown larva with green marks and patches, brought up under the same conditions as the last described.

The larvæ represented in figs. 3—7 were bred from eggs laid by one moth, and were fed on the same food. It is interesting to note considerable individual differences among the dark and light forms respectively. The stimulus being the same, the reaction differs somewhat according to individual predisposition.

Fig. 8.—A large mature green larva of *Amphidasis betularia* (one of the results of the 1889 experiments), shown in a very characteristic attitude on a green twig of *Populus nigra.* The brownish shade over the dorsal area is more or less present in the majority of green larvæ of this species.

Fig. 9.—This and all remaining figures represent the results of the 1892 experiments.

This bright green larva was the single exception found in a lot of 34 exposed to dark surroundings (Experiment I.). It is represented upon a twig of *Quercus cerris*, which serves to show the nature of the conditions employed. It became mature much before the other larvæ, and probably passed through the most sensitive period before the experiment began. Compare its size with that of fig. 10 from the same experiment.

FIGS. 11 and 12.—Two larvæ from Experiment II. They had been subjected to dead brown twigs of some species of *Salix*, the appearance of which is seen in these figures. One larva (fig. 12) is rather lighter and greyer than the other, but the resemblance to the surroundings is very strong; and no greater divergence occurred between any of these larvæ than that shown in figs. 11 and 12.

FIG. 13.—Three larvæ were transferred from the last Experiment (II.), and were exposed to green surroundings (XXVII.) from July 27th to the end of larval life. On Aug. 10th a drawing of the lightest one was made, and is reproduced here. The effect was but slight, the larva being rather lighter and greyer than any in II. It is represented upon a twig of *Populus nigra*.

FIG. 14.—A typical result of Experiment VI. is shown in this figure. The posterior claspers of the larva are fixed to a dead brown ivy leaf, thus showing the appearance of the environment with which most of the larvæ harmonised well, and from which only one differed considerably. The painting was made about Aug. 5th

FIG. 15.—A greenish white larva from Experiment XXVIII., resting on one of the white paper spills which formed the environment. The larva was mature when it was painted about Aug. 5th.

FIG. 16.—A brownish white larva from XXVIII., also resting on a white paper spill. When it is remembered that these were examples of the *least* white larvæ in this experiment, the effect of the white spills is seen to be most remarkable. A whitish larva, exhibiting no tendency to brown or green, was selected for painting, but it began to pupate, and altered in appearance before this could be accomplished.

FIG. 17.—A dark purplish brown larva from Experiment XXXI., resting on a dark blue paper spill. All the 10 larvæ in this set assumed this particular shade of brown. The larva was painted about Aug. 5th.

FIG. 18.—Abdominal segments 1 to 4 (indicated by numbers) of an intermediate larva, divided along the median ventral line, and spread out flat, as seen from the internal surface. The digestive tract has been removed. The tracheal system is shown on the left hand only. The arrow indicates the anterior direction. The

anterior brown band in each segment and the brown median dorsal stripe are due to true pigment in the epidermic cells, while the broader green band crossing the posterior part of each segment is due to green fat lying beneath the epidermis, which is of a pale yellowish colour over it. The yellow patches on each side of the middle line in the anterior part of each segment are due to part of the more deeply placed yellow fat.

PLATE XV.

FIGS. 1 and 2.—The dark and light varieties of the larvæ of *Catocala elocata*, obtained in the experiments described on pp. 302, 303. The larvæ are represented about three-quarters of the natural size, and the difference in shade was far greater than appears from these figures.

FIG. 3.—The dark and light larvæ of *Hemerophila abruptaria*, obtained in the experiments described on pp. 316, 317. The larvæ are represented about three-quarters of the natural size, and the difference of shade is very well expressed.

FIG. 4.—A lamp-shade, like that used in Experiment IV. upon *Amphidasis betularia* (1889), see pp. 331, 332. In front of and beside the lamp-shade are represented the five pieces of stick which were used in the experiment. The figure is about one-fourth the real size of the articles. These pieces of stick, placed among the green leaves of nut in the cylinder, turned far more than half the larvæ dark.

FIG. 5.—About one-fifth the real size. The conflicting colour case used chiefly in the experiments on *Vanessa urticæ* and *V. io* (see pp. 391—397 and 420—426). A complete description of it is given on p. 393). The difference between the alternate strips of gilt and black paper is not distinct, although it can be made out.

FIG. 6.—About one-fifth the real size. The conflicting colour case used in the experiments on *Vanessa io* (see p. 425, where the case is described). The distinct white spots in this and the last figure represent the bosses of silk spun by the larvæ. In use, the cover (the upper part of the figure) was placed over the compartments (the lower part), so that the white compartments had a black cover, and *vice versâ*, and the dorsal and ventral surfaces of the larvæ within were subjected to opposed conditions.